Spoken Word Recognition in Cantonese:

Significance of Onset, Rime and Tone in Monosyllabic Words

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ABSTRACT

This research aims at investigating the importance of onset, rime and tone in recognition of spoken monosyllabic words in Cantonese. We have conducted 4 auditory-auditory lexical decision priming experiments and recruited a total of 160 university students as participants. In Experiments 1, 2, and 3, participants were presented with word and nonword primes, constructed by altering one of the three sub-syllabic features, onset, rime, or tone, and made lexical decisions on word or nonword targets. Experiment 4 used the same task except that only nonword primes were presented, which were derived by altering two sub-syllabic features. All four experiments showed clear priming effects of nonword primes on word targets. The results supported that any one sub-syllabic feature sufficed to facilitate word recognition, and they had comparable contribution to word recognition. This suggested that the difference between the importance of segmental information and that of tone information in lexical activation might be negligible. The results also showed that in words, lexical activation could not take place in the absence of any one feature. On one hand, the present study revealed the significance of sub-syllabic features on lexical activation. On the other hand, it also acknowledged the dominance of lexicality over sub-syllabic features. Finally, by comparing the predictions of the four major spoken word recognition models on the results of our experiments, we suggested that the TRACE model (McClelland & Elman, 1986) was the best-fit model of the present findings.

論文摘要

本研究旨在探討聲母、韻母與聲調於識別口語粵語單音節詞之重要性。我們進行了四個聽覺詞彙判斷啓動實驗，並徵募了一共 160 位大學生爲參與者。在實驗一、二及三，參與者會聆聽字或非字的啓動詞，所聆聽的啓動詞乃是由改變字的其中一種音節成分，即聲母、韻母或聲調而成。參與者於聆聽啓動詞之後，會聆聽字或非字的目標詞，然後對目標詞作出詞彙判斷。實驗四採用同樣的任務，然而其中的啓動詞只有非字，並且這些非字乃是由改變兩種音節成分而成。四個實驗清楚顯示非字的啓動詞對字的目標詞的啓動效應。實驗結果支持任何一種音節成分足已幫助詞語識別，並且三者對詞語識別有相若的貢獻，這也證明了切分信息及聲調信息對詞語激活，可能並無顯著的分別。結果亦顯示在缺乏任何一種音節成分的單字的情況下，詞語激活不可能發生。本研究一方面顯露出音節成分對詞語激活的重要性，另一方面承認詞彙狀態比音節成分的優越性。最後，我們比較了四個重要的口語字詞識別模型對本實驗結果的預測，我們認爲 McClelland 及 Elman 於 1986 年提出的 TRACE 模型最能解釋本實驗的結果。

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TABLE OF CONTENTS

List of Tables

List of Figures

Chapter 1 – Significance of Onset, Rime and Tone in Monosyllabic Words

Spoken word recognition concerns how a listener accesses lexical representations in the lexicon and its lexical information according to bottom-up, that is, sensory, and top-down, that is, contextual information (Frauenfelder, 1996). This research area has long suffered from neglect until the last two decades (Tyler & Frauenfelder, 1987). Most psycholinguistic research was done on written words, and parallelism has long been assumed between written and spoken word processing. Within the last two decades, researchers began to explore the different phases involved in spoken word recognition, that is, access, selection, and integration (Marslen-Wilson, 1987). It is generally accepted that spoken word recognition involves the activation of a set of lexical candidates. Afterwards, the target word is selected from these activated candidates. There are four important models of spoken word recognition: COHORT I (Marslen-Wilson & Welsh, 1978), COHORT II (Marslen-Wilson, 1987), TRACE (McClelland & Elman, 1986), and SHORTLIST (Norris, 1994). Each model has its own way of accounting for these recognition phases.

In this study, the importance of sub-syllabic, or phonemic representations and how they achieve successful recognition of spoken words were investigated. We focused on Cantonese, one of the major dialects in Chinese. However, research on spoken word recognition is much less in Chinese language than in English or other Indo-European languages. Therefore, we first reviewed the latest findings on English, with which many research has been done, so that we could have a general picture and understand what are the important research questions of this research field. In the following review, we first introduced the constituents of monosyllabic words in English, which are onset and rime, and their significance in English and Indo-

European languages. We then moved to Cantonese to review the structure of monosyllabic words, and presented the latest findings on the significance of onset and rime in Cantonese. Afterwards, we focused on another feature, tone, a specialized feature in tone languages, and described its prevalence and significance. Finally, we gave an account on why a comparative study in Cantonese is needed and presented the objective and research questions of the present study.

Throughout the whole article, we would use terms including "word", "syllable" and "word onset". Except that when we mentioned words in general, or if it was specified like "polysyllabic word", we referred "word" to as "monosyllabic word". In the following sections, the words "word" and "syllable" interchanged sometimes, since they are actually the same in monosyllabic words. Nonetheless, readers should notice that the focus of our study is on monosyllabic words instead of syllables. Besides, when we mentioned "word onset", we referred it to as the "onset of monosyllabic words". This is applicable when we talked about "rime" and "tone".

Structure of Monosyllabic Words in English

English words can be decomposed into more basic units, syllables, and they may be either monosyllabic or polysyllabic. In linguistics, there are four different hypothesized internal structures of English monosyllable (Fowler, Treiman, & Gross, 1993). The first view is the linear view, which means that a syllable has no internal structure but only a sequence of phonemes. The second view is the theory of flat syllable, which proposes that the phonemes are grouped into three units, an onset, a nucleus and a coda. The onset and the coda refer to the prior consonant and the posterior consonant respectively, while the nucleus refers to the vowel. There is only affinity *within* the same unit but not *between* units. The third view is the hierarchical structure, which means that there are groupings between onset, vowel, and coda.

There are two possible hierarchical structures, which differs in the grouping of vowel with onset and with coda: The *onset-rime* structure assumes that the vowel groups with the coda to form the *rime*, while the *body-coda* structure assumes that the vowel groups with the onset to form the *body*. The fourth view is the moric theory, which states that syllables are composed of units called moras, and the vowel is always in the first mora, and the coda in the second, while a long vowel is in both moras.

Among these theories, the onset-rime version of the hierarchical structure is perhaps the most widely accepted because many linguistic phenomena can be explained when the rime is treated as a unit. Besides, experimental findings and statistical studies of syllable phonotactics have provided support for this structure. Treiman and her associates have conducted a series of experiments to support the onset-rime structure of syllables (Fowler et al., 1993; Treiman, 1986; 1988; Treiman, Fowler, Gross, Berch, & Weatherston, 1995; Treiman & Kessler, 1995). For instance, in Treiman (1986), when participants were asked to combine two words into a new word by using part of the first word and part of the second word, they tended to divide the words in an onset-rime fashion. Consistent results were found no matter whether the onset had a different number of consonants (one, two, or three), or the onset had a different category of phonemes, and no matter whether the listeners were college students or 8-year-old children.

In analyzing words in an English dictionary, Kessler and Treiman (1997) found that the vowel is significantly associated with the coda but not with the onset. In addition, an analysis was done by De Cara and Goswami (2002) on a corpus of monosyllabic English words to study the distribution of different phonological neighbors, including rime neighbors (words that share the same rime), consonant neighbors (words that share the same initial consonant), and lead neighbors (words that share the same onset-vowel sequence). Results showed that the most prevalent neighbors are rime neighbors. These studies again provide converging evidence for the onset-rime structure.

From the above findings, we can see that there are established internal structures within a syllable and associations between phonemes that we should not overlook. It is reasonable for us to treat syllables with an established structure, instead of treating a syllable as merely a sequence of phonemes. In this study, we would like to study the role of these established sub-units in a syllable. Following the line of research by Treiman and others (De Cara & Goswami, 2002; Fowler et al., 1993; Kessler & Treiman, 1997; Treiman, 1986; 1988; Treiman, Fowler, Gross, Berch, & Weatherston, 1995; Treiman & Kessler, 1995), we would like to study the role of onset and rime, which are the two basic units in hierarchical structure in spoken word recognition. Specifically, we want to know how these basic lexical building blocks contribute to the recognition process. In the following, the latest findings on the role of onset and rime in general are reviewed.

Significance of Onset and Rime in English and Indo-European Languages

Contemporary research on spoken word recognition has assigned different importance to word onset. The question of whether word onsets have a special status in lexical activation of spoken words has attracted debate over the past two decades (Cole, 1973; Connine & Clifton, 1987; Connine, Blasko, & Titone, 1993; Connine, Blasko, & Wang, 1994; Ganong, 1980; Marslen-Wilson et al., 1978; Marslen-Wilson & Zwitserlood, 1989; McClelland et al., 1986; Milberg, Blumstein, & Dworetzky, 1988; Nooteboom, 1981; Salasoo & Pisoni, 1985; Samuel, 1981; Slowiaczek, Nusbaum & Pisoni, 1987). Researchers had two opposing views regarding this issue (Marslen-Wilson et al., 1989): One view is that lexical activation is strongly directional, that is, the lexical candidates activated during recognition are solely determined by word onset. The other view is that word onset is less important than the overall goodness-of-fit between the input and the lexical representation.

Nooteboom (1981) mentioned three important reasons to support the first view. First, word onsets are important because they are produced first in speech production and perceived first in speech perception. Second, word onsets are found to be more informative and less redundant than word finals in languages like English and Dutch. Third, word onsets are less affected by assimilation and coarticulation compared with word finals in many languages.

On the other hand, there are two reasons supporting the claim that word onset is less important than the overall goodness-of-fit between the input and the lexical representation (McClelland et al., 1986). The first is that, if recognition system does rely solely on word onset, then there should always be sufficient information at onset for successful recognition. However, this condition is not always fulfilled in normal daily utterances. If the directional view is correct, then the recognition system cannot tolerate even a small variability in the sensory signal, which is normal in daily utterances. This creates a possibility that the target word may be dropped out easily because of variability and never be processed. This bears the risk of "making the recognition process too sensitive to noise and variations in the sensory input" (Marslen-Wilson, 1987). This is contrary to what has been found in the human spoken word recognition system, with which small changes in the speech signal are often undetected (Cole, 1973; Marslen-Wilson et al., 1978). For instance, Cole (1973) found that over 70% of small changes in a word are not detected when it is presented in a context of utterance. Besides, researchers also discovered that words could be recognized even with distorted beginnings (Cole, 1973; Marslen-Wilson et al., 1978).

Another reason is that, given a continuous speech sound sequence, listeners may not always have sufficient information on the location of the onset of each word.

Marslen-Wilson et al. (1989) have conducted a cross-modal priming experiment which supported the claim that word onsets have a special status in word recognition. In their experiment, auditory word or nonword primes were constructed by altering the onset of a word. The participants were presented with the primes and then the visual targets, which might be semantically related or unrelated to the primes. They were required to make a lexical response to the targets. The priming effect was determined by comparing the lexical decision time on the targets which followed the related primes and the targets which followed the unrelated primes. Results showed that only the original word primes gave a significant facilitation effect. No priming effect was given by the primes with altered onsets, no matter it was a word or nonword prime.

Contradictory results which showed that lexical activation could occur with distorted word onset have also been found. Ganong (1980) and Connine et al. (1987) have studied how listeners identify ambiguous word initial phonemes. They found that even when listeners heard words on a continuum ranged between a word and a nonword, they tended to categorize it as a word. For instance, when they heard a phoneme that was ambiguous between a /d/ and a /t/, they tended to categorize as /t/ when it was followed by /ask/ to form the word /task/. This showed that lexical activation could occur even with an ambiguous word onset. Connine et al. (1994) have investigated whether perceptual lexical ambiguities could activate their compatible lexical representations using cross-modal priming. In their experiments, auditory perceptual ambiguous tokens, such as an ambiguity between the words *glass* and *class*, were created. These were followed by visual targets, which were semantically related to the prime such as *drink* and *room*. The lexical decision times on the related targets and unrelated targets were then compared. A significant advantage was found in related targets over unrelated targets in lexical decision time. This again showed that lexical activation could occur even with a perceptually ambiguous word-initial phoneme. Furthermore, some researchers have found that lexical activation could occur when listeners were given input other than word onsets. Samuel (1981) found comparable effects of phoneme restoration at word initial, medial and final positions. Salasoo et al. (1985), using a gating task, showed that participants were able to produce words correctly given partial word-ends.

In-between these two contrasting views, some researchers have suggested a "milder" view regarding the status of word onset: That is, lexical activation need not be determined solely by the word-initial information. However, initial phonemes do have a privileged status on lexical activation. Quite a number of researchers have chosen this more flexible view (Connine et al., 1993; Milberg et al., 1988; Nooteboom, 1981; Slowiaczek et al., 1987). Nooteboom (1981) investigated the importance of word initials and word finals in lexical retrieval. The participants were presented with fragments, either of initials or finals, of Dutch words auditorily, and responded by completing and producing a word from these fragments. If the participant was not able to complete the word, he or she was to reproduce the fragment heard. It was found that listeners were able to retrieve the word correctly no matter whether they were presented with fragments of initials or finals. However, the probability of correct retrieval was higher and response time was shorter for initials than finals, showing that retrieval is easier for initials than finals. This is clearly a result which the strictly directional view cannot explain. As claimed by Connine et al. (1993), an initial phoneme may "require a greater degree of overlap with a lexical representation in memory than phonemes in noninitial positions".

Slowiaczek et al. (1987) have employed phonological priming to study lexical activation of word candidates. In their study, participants were to perform a perceptual-identification task. Participants were presented with auditory primes and targets which overlapped by different number of phonemes either from the beginning or from the end of the words. Two important results were given by this study. First, when the primes and targets did not overlap, or overlapped by one phoneme from the word beginning, there was no difference in identification time between the primed and unprimed targets. However, when they overlapped by two or three phonemes, or were identical, the primed targets were identified better than the unprimed targets. This again showed that the influence of word initials on word recognition should not be all-or-none, but instead depend on how much the input overlap with the lexical representation. Second, a similar result was found with word ends. That is, the rate of correct identification of the target increased as the phonological overlap between the prime and the target increased from the ends of the words. This supported that lexical activation could occur no matter whether phonological overlap was at word initials or word ends. The explanation that Slowiaczek et al. (1987) provided was that the advantage for word-initial information in speech perception may "simply be a temporal one".

Milberg et al. (1988) have also conducted an auditory-auditory lexical decision task to study the relationship between lexical activation and word-initial phonemes. Participants were presented with target words which were preceded by either semantically related words, nonwords in which the initial phoneme was distorted by one or more phonetic features, or unrelated words. They found a nearly linear relationship between phonetic distortion and facilitation. That is, the facilitation effect increased steadily from nonword primes to semantically related primes.

Connine et al. (1993) have employed a series of cross-modal priming experiments to study whether nonwords with similar initial phonemes derived from a base word would be able to activate the base word. In their experiments, participants were asked to listen to auditory nonword primes, followed by visually presented related or unrelated targets. These primes were nonwords which were produced by changing the phonetic features of the initial phoneme of the base word. Results showed that the facilitation effect on lexical decision time of targets depended on the amount of overlap of phonetic features in initial phoneme between the derived nonwords and the base word. There was a facilitation effect in minimal-overlap stimuli but not in maximal-overlap stimuli. Their results again showed that lexical activation could occur with distorted initial information, but this depends on the amount of overlapping phonetic features. Besides, they also found that there was no difference in the priming effect between initial nonword primes and medial nonword primes. This suggests that word-initial phonemes might in fact be equally important as phonemes in other positions in lexical activation.

The over-emphasis on initial phoneme in past research originates from the directional view of spoken word recognition. The role of its counterpart, the rime, is in fact unclear. Unfortunately, research on the role of rime on spoken word recognition is rare. In fact, past experiments were done almost exclusively on initial consonants until the past few years. Before then, the function of vowel and any other sub-syllabic structures has to be inferred from what is found with the initial consonant. Van Ooijen (1996) and Cutler, Sebastian-Galles, Soler-Vilageliu, & Van Ooijen (2000) were the two main articles which address the issue of different contributions of consonants and vowels in lexical processing. Van Ooijen (1996) had devised a word reconstruction task to study the processing of consonant and vowel in terms of mutability (or variability). His study was initiated by the findings of McQueen, Norris, and Cutler (1994). McQueen et al. (1994) designed a word-spotting task, in which participants detected real words that were embedded in nonsense strings. In a post-hoc analysis, false alarms were reported, that is, participants misperceived nonsense strings as words, by making both vowel and consonant changes. Out of these incorrect responses, responses which involved vowel changes were far more common than those that involved consonant changes. This finding seemed to reveal that vowel identity is more mutable that consonant identity.

Van Ooijen (1996) further investigated this idea in a word reconstruction task. In this task, participants were asked to "reconstruct" nonwords into words by changing either one consonant or one vowel. For instance, when the participant heard the nonword *kebra*, they might either change the first vowel to form the word *cobra*, or change the first consonant to form the word *zebra*. It was found that participants changed vowels more readily than consonants, and more errors were made in changing a vowel than a consonant. This showed that vowels are more mutable, or more susceptible and open to change of identity. As claimed by van Ooijen (1996), "vocalic segments could have a comparatively flexible goodness-of-fit" in lexical retrieval.

Since then researchers began to focus more on the processing of consonants and vowels using the same task and in different languages, including Dutch, Spanish (Cutler et al, 2000), and Japanese (Cutler & Otake, 2002). A cross-linguistic study by Cutler et al. (2000) in Dutch and Spanish gave a similar and a much clearer result:

They found that Dutch and Spanish participants were faster and more accurate in changing vowels than consonants. When allowed free-choice to change either phonemes (a consonant or a vowel), they were more likely to change vowels than consonants. Cutler et al. (2000)'s comparative study has provided us an important insight on vowel processing. This is because in their study, they found similar results as in van Ooijen (1996), notwithstanding the different distinctiveness of vowels in English, Spanish, and Dutch: English has many similar vowels, while Spanish has only five distinctive vowels. Besides, they also rule out the possibility that this finding was due to the particular vowel-to-consonant ratio in English (Dutch and Spanish have different ratios compared with English). What we can learn from Cutler et al. (2000) is that the impact of vowel information on lexical selection may not be so strong as consonant information regardless of language. Similarly, Cutler and Otake (2002) have reported the same pattern of results in Japanese, that is, participants replaced a vowel more easily than a consonant in reconstructing nonwords into words.

The studies reported above focused on the processing of phonemes, instead of sub-syllabic structures (i.e., onset and rime). This is reasonable because the phoneme is regarded as the prominent processing unit in English. Nonetheless, even though these research did not deal with the rime structure (which is the focus of this study), I think their findings are worth mentioning. The way initial consonants and vowels are used reveals that representations at lower level than the syllable level have considerable differences that we should not ignore. Besides, we may also infer the role of rime, which is often equivalent to the vowel in monosyllables, from the above findings.

After introducing the structure of monosyllabic words and the role of sub-syllabic structures in English, we are going to have a similar review on Cantonese. Cantonese is one of the six or more major Chinese dialects (Kao, 1971). We will see that Chinese (or Cantonese) research is much less when compared with research on English and Indo-European languages reviewed above. This poses a serious inadequacy in understanding speech processing and in constructing a universal model of spoken word recognition.

Structure of Monosyllabic Words in Cantonese

Syllable is a basic phonological unit in Cantonese, and most Cantonese syllables coincide with a morpheme. Examples of monosyllabic words are *ngo5* 我 (meaning I) and *nei5* 你 (meaning you). Words are often constructed by compounding, and examples of polysyllabic words are *faa1 sang1* 花生 (meaning peanut) and *tou4 syu1 gun2* 圖書館 (meaning library). In Cantonese, syllable boundary is clearly marked, which contrasts with the unclear and arbitrary boundary in many languages.

Traditionally, the Cantonese syllable is divided into two parts, the initial and the final (Fok, 1974; Hashimoto, 1972). This way of division is termed "initial-final dichotomy" (Hashimoto, 1972). The initial is the initial consonant and the final is the remaining part of the syllable which includes the tone. The initial may be optional. The final includes a medial, a vocalic element, and an ending. This way of dividing the syllable is in fact similar to the onset-rime structure in English. Unfortunately, however, there is not much psycholinguistic research that opts for a particular syllable structure in Cantonese. As far as the author knows, there is little research in Cantonese which investigates how listeners divide a syllable or any statistical research to study the cooccurence of sub-syllabic structures. In this study, the author attempted to use the initial-final (or onset-rime) structure as a framework to tackle the question of how sub-syllabic structures work in the spoken word recognition process. Provided that a universal syllable structure *does exist*, we should find comparable syllable structures in English and in Cantonese. In the following, we review past research on onset and rime in Cantonese, and also summarize the latest findings in Cantonese tones, a special feature not found in English and other Indo-European languages.

Significance of Onset and Rime in Cantonese

The question of whether word onset has a special status in spoken Chinese has in fact not been investigated systematically before. Most past studies have made comparisons between onset, rime, and tone. Generally speaking, the findings suggest that onset has an essential role in recognizing spoken Chinese words. For instance, Chen and Yip (2001) had their participants judge whether two syllables were the same or different along different dimensions, i.e. onset, rime, tone, or the whole syllable. When they judged according to the whole syllable, they were faster to judge when the onset was different than the same in the two syllables. However, these previous findings cannot lead us to conclude whether onset must be present in lexical activation, or whether lexical activation could still proceed in the absence of onset. Manipulations should be made to determine the influence on lexical activation when word onset is absent in the speech signal.

Past researchers has studied the role of rime in comparison with tone, instead of rime *alone* in spoken word recognition in Chinese (Chen & Yip, 2001; Cutler & Chen, 1997; Tsang & Hoosain, 1979; Ye & Connine, 1999; Yip, 2001). Yip (2001) has employed a naming task to study the effect of phonological overlap in prime-target pairs. He found that participants named the target significantly faster when the prime and target shared in rime, while naming was inhibited when rime was not shared.

Prevalence of Tone in general

After reviewing the segmental features, onset and rime, let us examine another feature, the tone, which is found in tone languages. It is often misperceived that tone languages are rare, which is not correct in reality. In fact, about 60-70 percent of languages in the world are tone languages (Yip, 2002). The areas in which tone languages are found include Africa, East and South-East Asia and the Pacific, and the Americas.

Significance of Tone in Chinese

Compared with word onset, the role of tone is neglected in contemporary recognition models. Therefore, it is not clear how tone is incorporated in the process of spoken word recognition. It is not surprising because most research on spoken word recognition was done using English or other Indo-European languages, which are non-tone languages. They contrast with tone languages, such as Mandarin, Cantonese and Thai, which make use of tone, in lexical access. In tone languages, tones are a necessary component in determining the lexical identity of a word. They serve to differentiate different syllables just like a vowel or a consonant does (Kao, 1971). It is unfair that an accurate model of language processing which includes tone is not available, even though over a half of the languages in the world are tone languages.

Regarding the role of tone, a review on tone research showed that most past research focused on the perceptual dimensions of tone (Gandour, 1981; Gandour, 1983; Howie, 1976; Lin & Repp, 1989; Shen & Lin, 1991; Vance, 1977; Wang, 1967), or representation of tone (Taft & Chen, 1992). More recently, researchers have begun to focus on the role of tone in spoken word recognition and other higher-level spoken language processing (Cutler & Chen, 1997; Tsang & Hoosain, 1979; Ye & Connine, 1999).

Since tones are important for lexical access in tone languages, we may naturally predict that listeners should process tones with ease. However, quite many studies showed that it is not the case. Tone information was often processed with more difficulties than segmental information. Tsang and Hoosain (1979) presented pairs of Cantonese sentences that differed in one character to native Cantonese listeners. The difference could be in tone, vowel, or both. At each time, the listeners heard only one member from each pair of sentences and were asked to identify it afterwards. Results showed that the error rate was significantly higher for the tone difference than for the vowel difference. Besides, the error rate was not significantly different for the vowel difference and for the vowel plus tone difference.

Similarly, Cutler and Chen (1997) showed that listeners encountered more difficulties in processing tone information than in processing segmental information. Two paradigms were used in their study: lexical decision and same-different judgment. In the lexical decision task, native Cantonese listeners were asked to determine whether a Cantonese disyllable was a real word. The onset, vowel, and tone of the second syllable were altered to give different combinations of nonwords. In this experiment, the error rate of tone-mismatch condition was found to be higher than that of any other conditions. Also, in the same-different judgment task, the same participants were asked to determine whether two single Cantonese syllables, either words or nonwords, were the same or different. The second syllables were altered in their onsets, vowels, and tones. It was found that response time was longer and error rate was higher when the only difference between two syllables was in tone. Cutler and Chen (1997) suggested that there was possibly a temporal delay in the availability of tone information compared with segmental information. They suggested that the availability of phonetic information followed the order: onset, vowel, and finally tone. They proposed that the perceptual disadvantage of tone made it more difficult to utilize tone information than to utilize segmental information. What is more, in their study, the same-different judgment task was replicated and a similar response pattern was found with a group of native speakers of Dutch, who had no knowledge of Cantonese. Cutler and Chen (1997) interpreted the result that the processing of tone information was "simple perceptual processing" which could occur in the absence of linguistic knowledge.

Ye and Connine (1999) investigated Mandarin tone using the tone-vowel detection task with native speakers of Mandarin. In their experiments, participants had to detect a target tone-vowel combination. Therefore, participants had to pay attention to and process both vowel and tone information during the detection process. Similar to Cutler and Chen (1997), it was found that response times were longer with tone-mismatch items than with vowel-mismatch items.

Why a Comparative Study in Cantonese is needed

With a view to the previous summary, we can see that the roles of onset, rime, and tone still need to be investigated more deeply, no matter as a universal question or as a specific question about Chinese language processing. Cutler (1997) has made a reasonable account of why a universal model of spoken language is needed, and why we should conduct comparative research on spoken language. Obviously, no one is born to learn a particular language only. A person can acquire a different language provided that he/she has no inborn learning difficulties and that the appropriate environment is available. Therefore, there should be universal rules that govern spoken language processing, even though language-specific properties may prevail in different language users. To achieve a universal model, comparative research on different languages is necessary to grasp the different characteristics that each language possesses. A good example is the finding of Cutler et al. (2000) mentioned above, which contrasted English, Dutch, and Spanish to give a cross-linguistic proof of the high mutability of vowels compared with consonants.

Similarly, a comparative study using Cantonese as the target language should provide us with valuable insights given its many distinctive characteristics. For instance, Cantonese is a tone language which is rich in number of tones compared with other tone languages. This helps us incorporate the prosodic feature into the spoken word processing, which often emphasizes the segmental processing owing to the great number of English language studies.

Altogether, the present study of Cantonese can provide insight in two directions: The first is that we can determine the language-specific processing in Cantonese, including whether there is special status of onset, the comparative role of onset and rime, and whether tone is processed in the same way as segmental information. The second is that we can use the present finding to generalize to the universal process of spoken word recognition. We may use the present findings to verify whether the directional view is reliable, and see how the role of tone can be included in the existing word recognition models, so that a more comprehensive model can be achieved.

Objective and Research Questions

The present study attempted to identify the role of word onset, rime, and tone in spoken word recognition. Three research questions are addressed in this study: (1) Is lexical activation determined by word onset *only*, or instead, by the overall goodness-of-fit between the input and the lexical representation? (2) To what extent does rime structure contribute to the recognition process? (3) Is the processing of tone more difficult than the processing of segmental features including word onset and rime?

Chapter 2 – General Methods

Four experiments were carried out in the present study. The general research methodology of the first three experiments is described here, including the design, materials, apparatus, and procedures. They are the same in all three experiments and hence will not be mentioned again.

Design

We have used auditory-auditory priming lexical decision in the present study (Goldinger, 1996). As noted by Goldinger (1996), the auditory lexical decision task provides relatively on-line data and has been used to study many phenomena in word recognition, such as word frequency effect, semantic and phonological priming effects, etc. Besides, the lexical decision task can easily blend with priming procedure. In this study, we want to study when the sub-syllabic information of a prime word is altered, will the same prime word be activated? If the prime word is activated, then this activated prime word should be able to prime its associated target word. We have therefore chosen the auditory lexical decision, together with the priming manipulation, to study the association priming effect.

Another very commonly used paradigm to study spoken word recognition is cross-modal priming (Connine et al, 1993; Connine et al, 1994; Marslen-Wilson et al., 1989). In this paradigm, visual targets are presented for lexical decision after spoken words or nonwords are presented. We did not choose this paradigm because difference is observed by auditory and visual lexical decision tasks. One example is Chen and Cutler (1997). Chen and Cutler (1997) used two paradigms, auditory-auditory priming lexical decision and auditory-visual priming lexical decision (i.e. cross-modal priming), in investigating spoken word recognition in Cantonese. They used disyllabic Cantonese words as stimuli and manipulated the target word in three ways: an unrelated word, a semantically related word, or a phonologically related word. Interestingly, they found significant phonological and semantic facilitation in only the former but not the latter task. They claimed that phonological and semantic priming effects were modality-specific and the role of phonology was different in auditory word recognition than in visual word recognition. Therefore, to ensure that the priming effect would not be affected by the different modalities, we decided to use auditory-auditory priming lexical decision as the paradigm so that both the prime and the target are presented in the same modality.

Two independent variables were manipulated in this study. They were both within-subject variables:

(1) Onset/rime/tone: One of these aspects of the word was altered in each experiment.

(2) Lexical status: The test items were either words or nonwords, so as to enable us to investigate the influence of the lexical status of the word in recognition. This is essential in our study for two reasons. First, the nonword conditions served as the baseline for comparison, so that any priming effect could be found. Second, the different speech models disagree on whether lexical activation would be produced with a nonword input. In other words, they have different predictions on whether a priming effect would appear in the nonword conditions. Therefore both word and nonword conditions are necessary in our study.

The dependent variables were the reaction time and the error percentage.

Five experimental conditions resulted from crossing the two independent variables:

Condition 1 (Original word): In this condition, a word prime was presented followed by its associated target. The size of priming effect of original word can be estimated by comparing the reaction time to original word with that to word baseline.

Condition 2 (Onset-altered word; Rime-altered word; Tone-altered word): In this condition, word primes were constructed by altering either the onset, rime, or tone of original word, depending on the experiment. These word primes were followed by the same targets of the original word. A comparison between original word and Condition 2 can tell us how much effect the onset, rime, or tone has on the priming effect.

Condition 3 (Onset-altered nonword; Rime-altered nonword; Tone-altered nonword): In this condition, nonword primes were constructed by altering either the onset, rime, or tone of original word and followed by the same targets of original word. Any effect of lexical status can be estimated by comparing responses to Conditions 2 and 3.

Condition 4 (Word baseline): In this condition, single words were chosen as primes which had no phonetic relation with the primes or with the targets of original word, nor did they have any semantic relation with the targets. This condition served as the baseline for estimating the priming effect in word conditions.

Condition 5 (Nonword baseline): In this condition, the items were manipulated in the same way as did the word baseline, except that nonword primes were chosen. This served as the baseline for estimating the priming effect in nonword condition.

Materials and apparatus

In each of the experiments, a pool of monosyllabic word pairs, which served as primes, was first constructed. The word pairs were all nouns in the present study. We further select the appropriate test items by presenting these word pairs to pilot subjects. Cantonese is a language with high degree of homophony. This means that two words can have exactly the same pronunciation but different meanings. Therefore, we had to make sure the word that our pilot subjects judged was the one we presented to them, but not its neighboring homophones. To do so, the member of each word pair was embedded in a carrier, which was a disyllabic, meaningful compound word. For instance, the word *bing1* 冰 (meaning ice) was embedded in the compound word *git3 bing1* 結冰 (meaning freeze) to form the item "結冰嘅冰" (meaning "ice" in "freeze").To make the tables simple, the carrier compound words were not shown in appendices. The compound word served to restrict which homophone was presented.

We checked the familiarity of the word pairs and the associative strength between the primes and their corresponding targets. We wanted to ensure that the two members of each word pair would have comparable familiarity. This was done by distributing a written questionnaire to a group of pilot subjects. Items such as "結冰嘅冰" (meaning ice in freeze) were presented to a separate group of 30 native Cantonese speakers (who did not participate in the priming task) on a written questionnaire. These pilot subjects were asked to rate their subjective familiarity of the words. Their ratings were made on the basis of a 6-point scale (1: very familiar; 2: moderately familiar; 3: slightly familiar; 4: slightly unfamiliar; 5: moderately unfamiliar; 6: very unfamiliar). Mean familiarity scores were then calculated for each word.

In addition, a free association task was done to choose a target for each word and also check the associative strength between the primes and their corresponding targets. The disyllabic words were presented to another group of 30 native Cantonese speakers (again, they did not participate in the priming task). In this task, they were asked to write down the first word that came to mind, which could follow the word to form a meaningful, disyllabic word. For instance, when they read the word *git3 bing1* 結冰 (meaning freeze), they had to think of a single word which followed *bing1* 冰 (meaning ice). An example is seoi2 水 (meaning water), and the resulted word is *bing1 seoi2* 冰水 (meaning iced water). They were asked to write down as many words as possible, with a limit of three words. The associative strength of each target word was calculated by dividing the number of response of a target word by the total number of response expected from all pilot subjects (i.e. 30).

Twenty word pairs were then chosen as the test items, according to the familiarity ratings and the results in the free association task. The test items were chosen with regards to the following criteria, which were employed in a similar study by Marslen-Wilson & Zwitserlood (1989):

(1) The two members of each word pair should have comparable familiarity.

(2) The words chosen should have an overall associative strength with their corresponding targets of not less than 16%. It was the value used by Marslen-Wilson & Zwitserlood (1989), which we regarded as an acceptable value.

(3) The targets chosen should form a meaningful disyllabic noun with its corresponding prime. Examples are *bo1 long6* 波浪 (meaning wave) and *ce1 leon4* 車輪 (meaning car wheel).

(4) Each member in the word pair should have no associative or semantic relation to the target of the other member in the same pair. For instance, the word *faai3* 塊 (meaning piece) was never given as a response to the word *sing1* 星 (meaning star) in the association task (Appendix I).

One problem that we have to solve with using auditory-auditory priming lexical decision is that, we have to make sure that the priming effect we have found is due to the activation at the lexical semantic, but not the sublexical level of representation. For instance, if we have the word *seoi2* 水 (meaning water) as the prime and *sau2* 手 (meaning hand) as the target, any priming effect found could possibly be due to two sources. One source would be at the sublexical level, as the two words share the same phoneme /s/ and the same tone. Another source would be the semantic relation between the two words, as the two words can combine to form a meaningful word *seoi2 sau2* 水手 (meaning sailor). Therefore, to ensure that the priming effect is purely located at the lexical semantic level, one more criterion was added in our study in choosing the items:

(5) Each member in the word pair should have no overlapping onset, rime, or tone with its corresponding target, or with the target of the other member in the same pair.

Appendix V showed the stimulus arrangement in Experiments 1, 2, and 3. For instance, in item 1, all the primes (A1 to E1) were presented with the same target word T1. The selected word pair, A1 and B1, formed the basis of the first two conditions. The word pairs were repeated such that when one member was in Condition 1, the other member would be in Condition 2, and vice versa. For instance, only A1 was associated with the target word T1. Conversely, in item 21, only B1 was associated with the target word G1. This formed the 40 items in both Conditions 1 and 2. For Conditions 3, 4, and 5, 20 items were constructed as described above and they were repeated so that there were 40 items in each condition. The familiarity of the words in Condition 4 was also checked so that the words in Conditions 1, 2, and 4 (all the word conditions) had comparable familiarity. There were a total of 200 test items (Appendix I, II, and III, the carrier compound words were not shown).

Since all the test items had word targets, 200 filler items with nonword targets were constructed so that there would be an equal proportion of "word" and "nonword" responses. There were altogether 400 items, and they were allocated into 10 blocks.

The stimulus arrangement in each block was shown in Appendix V. In each block, there were 40 items, 20 were test items and 20 were filler items. Remember that 3 out of the 5 experimental conditions were word conditions and 2 were nonword conditions. The word and nonword primes were therefore allocated according to this proportion. In each block, 12 test items had word primes and 8 had nonword primes. The filler items had the same allocation, that is, 12 word primes and 8 nonword primes. Besides, the test items were arranged so that each target appeared only once in each block. The trials were then randomized within each block. The 10 blocks were also randomized in the following way: The first participant began with a fixed order of blocks. Then the participants afterwards were tested by rotating this sequence systematically with each block moving one position to the left.

As described above, each target word appeared five times for the sake of making comparisons among the five experimental conditions. We could expect that this might influence participants' perception of the target words: a practice effect might occur in which participants might be familiarized with the target words and reaction time required for the target words might be reduced. This might create a confounding to the reaction times we obtained and made data difficult to explain. However, this possible confounding can be minimized to a large extent because of the stimulus arrangement we have made. First, each target word was presented only once within a single block. There were also rest intervals between each block. Hence there was a rather long time interval between each occurrence of a particular target word. Second, since there was randomization of trials within each block, a target word would not be presented in the same position in different blocks. The items preceding and following the target word were also different in different blocks. This randomization process could reduce the chance that participants might memorize the context in which a target word was presented. Third, since one target word is preceded by five different primes, it was not easy for participants to guess which target word would be presented. With a view to these manipulations, we expected that the possible confounding caused by practice effect could at least be reduced to a minimum.

Apart from test items and filler items, 12 practice items were constructed to familiarize the participants with the experiment. The practice items were distributed equally to each of the following combinations: word prime-word target, word prime-nonword target, nonword prime-word target, nonword prime-nonword target.

Both test and practice items were read at a comfortable rate by a male native Cantonese speaker in a quiet room. The items were tape-recorded, and then digitized into a computer file by Creative WaveStudio in a PC computer. Digitizing was done with a sampling rate of 48kHz and a 16-bit sound format. The items were isolated by locating their onsets and offsets in the speech waveforms and using auditory feedback.

Procedure

The participants were seated in a quiet experimental room individually. Before the experiment started, the experimenter explained to the participants the instructions of the experiment. Participants were then asked if they had any questions.

The experiments were controlled by a Java Program. The Java Program has provided sufficient temporal resolution (in milliseconds) for data collection. This timing accuracy is at an acceptable level which is also used in other priming studies (Connine et al., 1993; Connine et al., 1994; Marslen-Wilson et al., 1989). During the experiment, all the items were presented via two amplified Aiwa speakers connected to a PC computer. Before the experiment began, each participant was assigned an experimental sequence with which they would be tested. The participant was first familiarized with 12 practice trials, followed by the 10 experimental sessions. A break was given between each session, and the participant could continue the experiment whenever they felt the break was enough.

The participants had to pay full attention to the items in each trial. In each trial, a beep sound was first presented, signaling that a trial began. A 500-ms silence was then presented, followed by the prime and the target. There was a 500-ms interstimulus-interval between the prime and the target. The length of ISI was chosen according to the study by Milberg et al. (1988) reported above. As reviewed in introduction, Milberg et al. (1988) has used an auditory-auditory lexical decision task to study priming between target words and semantically related prime words or nonword primes constructed by altering the phonetic feature of the initial phoneme of the prime word. They found increasing semantic priming effects as the overlapping phonetic features increased. With a view to the significant priming effect reported, we decided to use the same ISI length in this study.

The participant's task was to judge whether the target was a Cantonese word or not. They were to make response on a button box by pressing the left button if a word was presented, and the right button if a nonword was presented. They had to respond as fast and as accurately as possible. Also, before the experiment began, the participants were reminded that they should make the response immediately after they made the lexical decision. This is because the reaction time was determined from item onset. The time limit of response was 5s. If no response was given after this time limit, another trial was presented automatically. The experiment lasted about 45 minutes.

Chapter 3 – Experiment 1

Hypothesis

Experiment 1 examined whether lexical activation was determined by the presence of word onset alone, or onset is less important than the overall goodness-of-fit of the input and the lexical representation. We expected that if the former hypothesis was supported, then there should *only* be priming effect in the original word condition, but not in the onset-altered conditions. On the contrary, if the latter hypothesis was supported, then there should be priming effect in either or both onset-altered conditions.

Method

Participants

Forty native Cantonese speakers (8 male and 32 female) were recruited. They were all students at the Chinese University of Hong Kong and were paid volunteers. None had reported any speech or hearing problems.

Design

In this experiment, we would like to investigate the importance of onset in spoken recognition of Cantonese word. The two independent variables were word onset and lexical status. The dependent variables were the reaction time and the error percentage.

The five experimental conditions were as follows: Original word (Condition 1), onset-altered word (Condition 2), onset-altered nonword (Condition 3), word baseline (Condition 4), and nonword baseline (Condition 5).

Materials

A pool of 36 monosyllabic word pairs and their associated targets was first constructed. They were constructed such that the member of each word pair shared the same rime, the same tone, but not the same onset with the other member. The familiarity of the word pairs, and also the associative strength between the primes and their corresponding targets were checked as described in the General Methods section. Twenty word pairs and their targets were then selected, which formed the forty items in Conditions 1 and 2 (Appendix I). Forty more words were constructed as items in Condition 4.

Procedure

The procedures are as described in the General Methods section.

Results and Discussion

Before the analysis, we noticed that there were some disyllabic homophones among the carrier compound words in our stimulus. What we meant by "disyllabic homophones" was that there were compound words which share the same sound. An example is *jyun4 bat1* (see Appendix II, item no. 2, carrier compound word not shown), which can mean either "pencil" (鉛筆) or "finish" (完畢). We checked it by presenting questionnaires to pilot subjects, asking them to write down the compound word and also their homophones, if any, that they have heard. Since a disyllabic homophone fails to restrict what the prime is, any items which had disyllabic homophones were excluded from analysis. There were 1, 2, and 1 disyllabic homophone in Conditions 1, 2 and 4 respectively. They were deleted together with the corresponding items in the other conditions (e.g. both *bing1* and *sing1* were deleted). Forty items were deleted and 160 items were left for analysis.

After the removal of disyllabic homophones, the mean familiarity and mean associative strength were checked and were still able to comply the criteria mentioned in the General Methods Section. The mean word familiarity of words in Conditions 1, 2, and 4 were 1.27, 1.33, and 1.36 respectively (i.e., from very familiar to moderately familiar). The word familiarity in Conditions 1, 2, and 4 was not significantly different [Conditions 1 and 2: $t(30) = -1.24, p > 0.05$; Conditions 1 and 4: $t(30) = -1.49, p > 0.05$; Conditions 2 and 4: $t(30) = -0.43, p > 0.05$]. Also, the mean prime-target associative strength in Conditions 1 and 2 was 27.81%.

Incorrect responses were first discarded so that only the RTs of correct responses were included in further analyses. There were altogether 1256 errors in the 6400 responses to test items (i.e. answering "no" to a word target). The average error percentage was 19.63%. Besides, reaction times longer than 2000 msec were also discarded. Mean reaction times, counted from stimulus onset, and mean error percentages were then calculated. Reaction times exceeding two standard deviations below or above the mean reaction times were further discarded for each participant and each item. The number of trimmed responses was 551, which amounted to 8.61% of all responses.

Mean reaction times and mean error percentages of the five conditions are shown in Figures 1 and 2. Repeated measures ANOVA was conducted with the prime type as the within-subject factor. There was a significant main effect of prime type on both RT [$F(4,156) = 16.01, p < .001$] and error percentage [$F(4,156) = 16.99, p < .001$]. A power of 1.00 was achieved for both RT and ER analyses.

Further analysis was conducted using the Newman-Keuls test with Statistica to locate which means were different. As expected, the original word condition had significant priming effect in both RT and ER compared with the word baseline [Priming effect: 68 msec in RT, $p < .001$; 8.98% in ER, $p < .001$]. It also gave significantly faster and the most correct response than the other four conditions did.

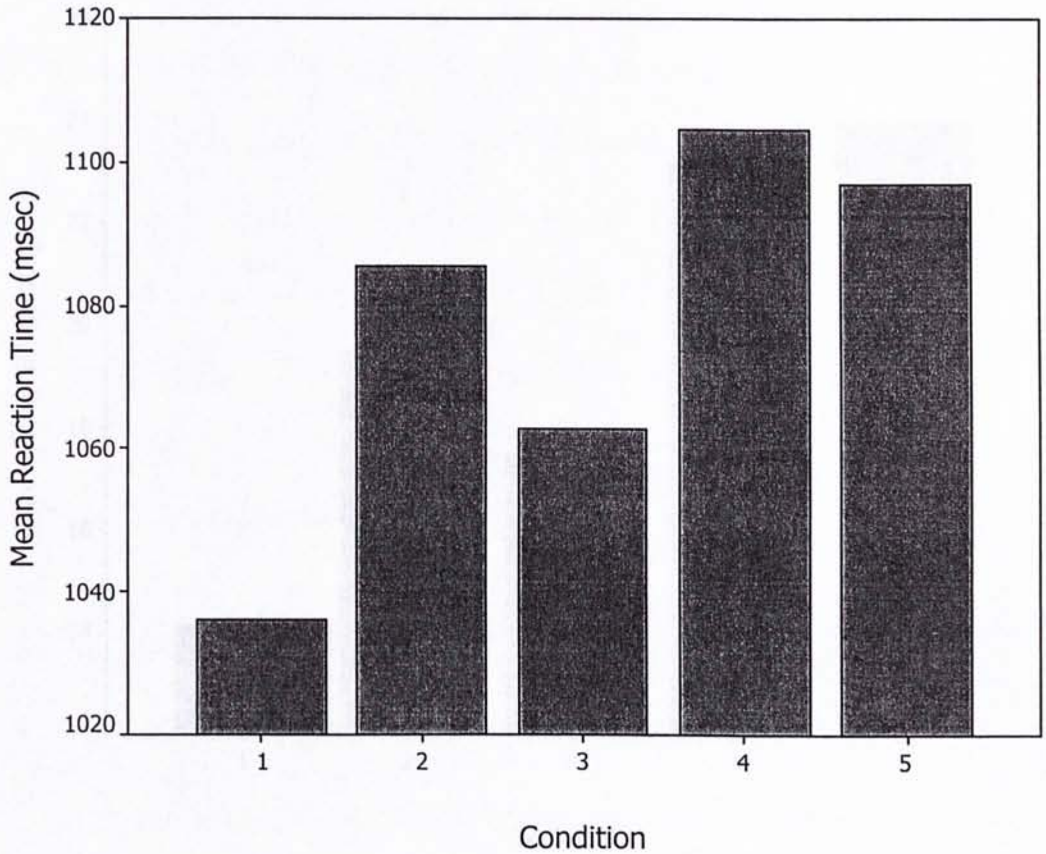

Figure 1. Mean reaction times in the five conditions in Experiment 1.

The critical point in our study is how word onset affects the recognition process. Results showed that priming effect was located in onset-altered nonword condition, but not in onset-altered word condition. Onset-altered nonword (Condition 3) gave significantly faster RT and lower ER than the nonword baseline [Priming effect: 34 msec in RT, $p < .005$; 6.41% in ER, $p < .001$]. It can be seen that the onset-altered nonword gave a half of the priming effect of the original word. Onset-altered word did not give significant priming effect in RT, but a lower ER compared with word baseline [3.67, $p < .01$], which is a small difference when it was weighed against the difference given by original condition or onset-altered nonword condition.

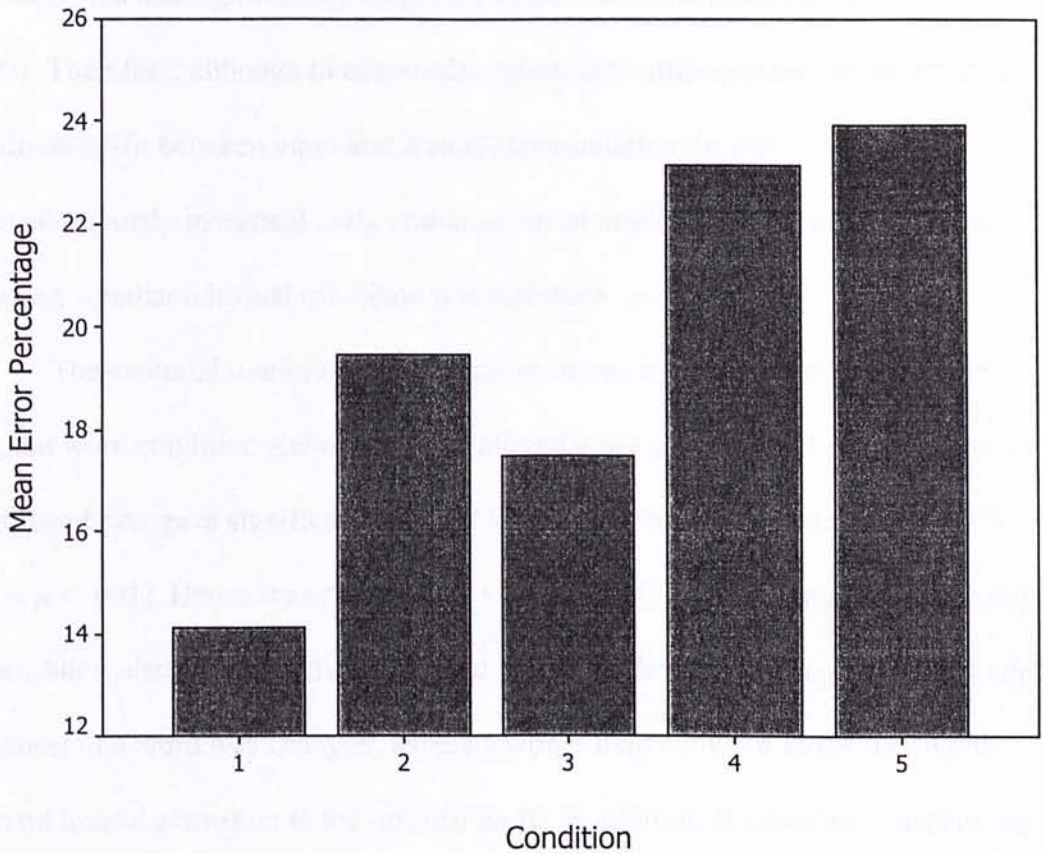

Figure 2. Mean error percentages in the five conditions in Experiment 1.

This finding *partly* supported our second hypothesis, that is, in the case of *nonword*, lexical activation is determined to a larger extent by the overall goodness-of-fit between the input and the lexical representation, instead of the mere presence of word onset. This is shown by the fact that onset was not available to produce priming effect, or lexical activation, in onset-altered nonword condition. It is obvious that rime and tone were sufficient for lexical activation to occur.

Another insight provided by this finding is that lexical status interacts with and predominates over sub-syllabic features so that no lexical activation could be produced in onset-altered words. The lexicality effect was more apparent when we compared the RT in onset-altered words and in onset-altered nonwords. The onset-altered words had significantly longer RTs than onset-altered nonwords [23 msec, $p < .05$]. Therefore, although in nonwords, lexical activation depends on the overall goodness-of-fit between input and lexical representation; in *words*, which we encounter mostly in normal daily utterance, word onset *does* have a major role in deciding whether a lexical candidate was activated.

The essential role of onset can also be shown by the RT difference in the original word condition and in the onset-altered word condition. The onset-altered word condition gave significantly longer RT than the original word condition [49 msec, $p < .001$]. Hence the onset-altered word not only gave no significant priming effect, but it also significantly lengthened the RT to the target. It suggested that when the onset of a word was changed, listeners would treat the word as another word, with no lexical activation to the original word. In addition, the fact that the priming effect of the onset-altered nonword was a half of that of the original word indicated that even in the case of nonword, the absence of onset did have a considerable impact on lexical activation.

Afterwards, we tried to compare our findings with that of Marslen-Wilson and Zwitserlood (1989). It was indeed difficult to make direct comparison between the two studies because of the many different manipulations employed. These included the different tasks (auditory lexical decision versus cross-modal priming), different languages (Cantonese versus Dutch), and different participants recruited. Nonetheless, they did have a crucial difference that we could mention here. It lies in the different results given by onset-altered nonword condition (the equivalence of nonword rhyme condition in the latter study), in which Cantonese listeners gave significant priming effect but not Dutch listeners. It had two possible implications. The first is that Cantonese listeners, or Cantonese, might assign higher importance to sub-syllabic features in nonwords than Dutch listeners or Dutch did. The second is that the auditory lexical decision priming task might have made the priming effect in nonwords easier to be shown. Which explanation is more appropriate remains to be solved by future researchers, who may conduct comparative study on the two languages using a same task.

There was also something similar in the present study and Marslen-Wilson and Zwitserlood (1989). When we compared the RTs of the two studies, we noticed that they showed a similar proportion of priming effect in the original word condition. The RT of original word condition and its priming effect in the present study were 1036 msec and 68 msec respectively, whereas they were 526 msec and 32 msec in Marslen-Wilson and Zwitserlood (1989). By dividing the priming effect by the RT of original word, both studies yielded a priming effect which was about 6% of original word's RT. This is an interesting finding, which showed that the priming effect is rather stable, no matter what tasks, participants, and languages were used. However, more evidence is obviously needed before we are able to conclude whether this finding occurred coincidentally, or it revealed the constancy of priming effect.

Chapter 4 – Experiment 2

Hypothesis

In Experiment 2, we investigated the importance of rime in spoken recognition of Cantonese words. We followed the line of research by Van Ooijen (1996) and Cutler et al. (2000) as reviewed in Introduction and we predicted that rime identity is more susceptible to change than consonant identity. We expected that listeners could accept rime change, since they could also accept onset change in Experiment 1. We deduced that a rime change in altered-rime conditions would not eliminate the priming effect in the original condition. We hypothesized that significant priming effect should be given in either rime-altered conditions, since a significant priming effect was also found in onset-altered nonwords in Experiment 1. At this moment, we did not address the question of magnitude, that is, whether rime-altered conditions gave more or less priming effect than onset-altered conditions. This is because two different sets of stimulus were used and they cannot be compared *quantitatively*. Here we only anticipate the *presence* of priming effect in rime-altered conditions.

Method

Participants

Forty native Cantonese speakers (11 male and 29 female) were recruited. They were all students at the Chinese University of Hong Kong and were paid volunteers. None had reported any speech or hearing problems and none had taken part in Experiment 1 or 3.

Design

The two independent variables were word rime and lexical status. The dependent variables were the reaction time and the error percentage.

The five experimental conditions were as follows: Original word (Condition 1), rime-altered word (Condition 2), rime-altered nonword (Condition 3), word baseline (Condition 4), and nonword baseline (Condition 5).

Materials

The materials were constructed as in Experiment 1. A pool of 45 monosyllabic word pairs and their associated targets was first constructed such that each member of the word pair shared the same onset, the same tone, but not the same rime with the other member. Again, the familiarity of the word pairs, and the associative strength between the words and their corresponding targets were checked as described in the General Methods section. Twenty word pairs and their targets were chosen, which formed the forty items in Conditions 1 and 2 (Appendix II). Again, forty more words formed the items in Condition 4.

Procedure

The procedures are as described in the General Methods section.

Results and Discussion

We have checked if there were disyllabic homophones in the stimuli like we did in Experiment 1. Forty items were deleted and 160 items were left for analysis. The words remained in Conditions 1, 2, and 4 had familiarity of 1.89, 1.92, and 1.89 respectively (i.e. from very familiar to moderately familiar). There was no significant difference in familiarity of words in Conditions 1, 2, and 4 [Conditions 1 and 2: $t(30) = -0.34, p > 0.05$; Conditions 1 and 4: $t(30) = -0.04, p > 0.05$; Conditions 2 and 4: $t(30) = -0.30, p > 0.05$]. The primes and targets in Conditions 1 and 2 had an overall mean associative strength of 20.31%.

Afterwards, the error responses (1222 out of 6400), which was 19.09% of all responses to test items were discarded and only RTs of correct responses were left for analyses. Reaction times longer than 2000 msec or exceeding two standard deviations below or above the mean reactions were further discarded. The number of trimmed responses was 574 (8.97% of all responses).

The mean reaction times and mean error percentages of the five conditions were shown in Figures 3 and 4. Repeated measures ANOVA was conducted with the prime type as within-subject factor. Mauchly's Test of Sphericity showed that the sphericity assumption was not met in RT analysis, so we adjusted the degrees of freedom according to the Greenhouse & Geisser (1959) epsilon. Significant main effect of prime type was found in both RT [$F(2.84,110.69) = 9.46$, $p < .001$] and error percentage [$F(4,156) = 8.99$, $p < .001$]. Power of 1.00 was calculated for both RT and ER analyses.

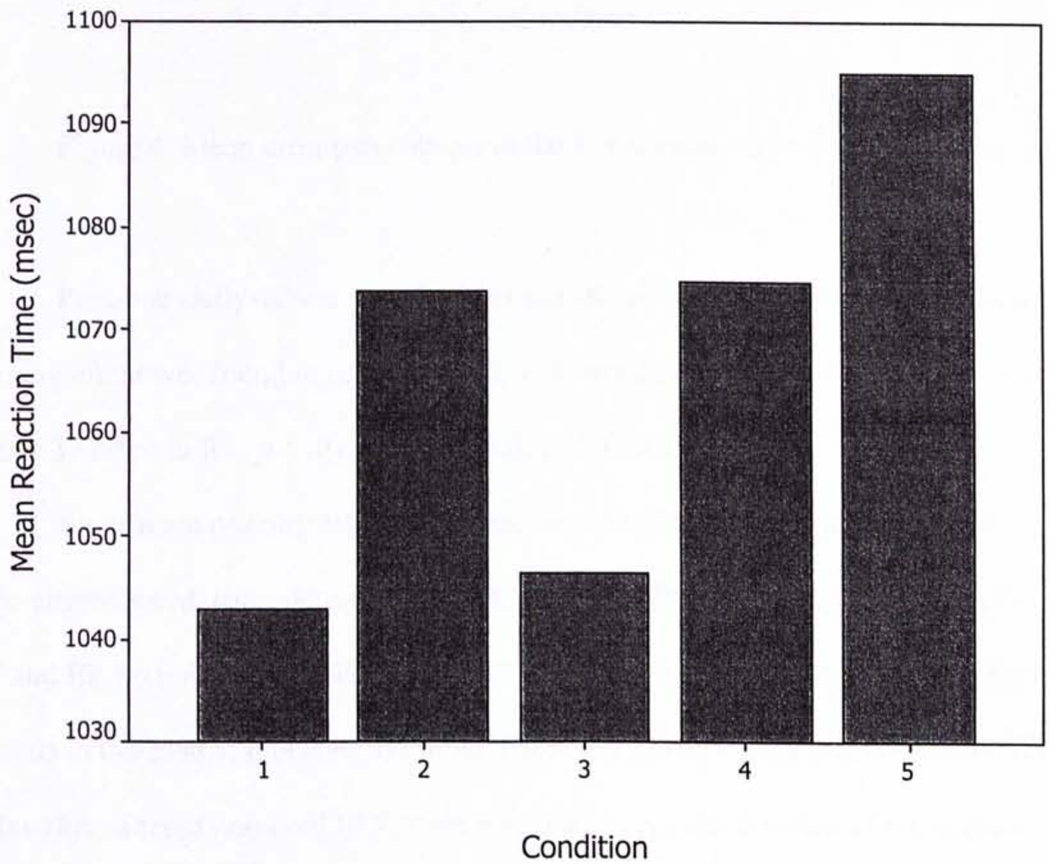

Figure 3. Mean reaction times in the five conditions in Experiment 2.

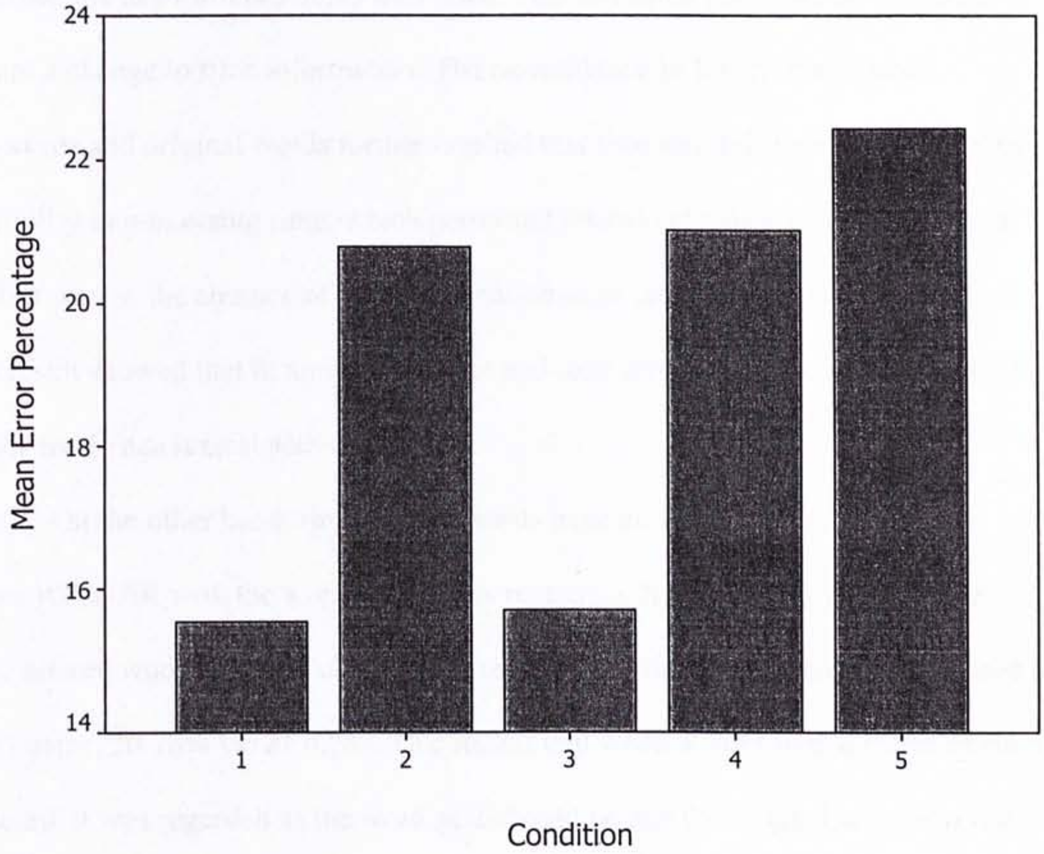

Figure 4. Mean error percentages in the five conditions in Experiment 2.

Post-hoc analysis was done by Newman-Keuls test. As predicted, significant priming effect was found in original word, with word baseline as reference [Priming effect: 32 msec in RT, $p < .01$; 5.47% in ER, $p < .005$].

Significant priming effect was found in rime-altered nonword, but not in rime-altered word. Rime-altered nonwords gave significant priming effect in both RT and ER [Priming effect: 49 msec in RT, $p < .001$; 6.72% in ER, $p < .001$]. With regards to the case of *nonword*, our hypothesis was *partly* supported. In fact, the RT of the rime-altered nonword (RT: 1046 msec) was very close to that of the original word (RT: 1043 msec). Also, it gave an even greater priming effect (49 msec) than the original word (32 msec) did, on condition that two different baselines (word baseline and nonword baseline) were used. This indicated that listeners could easily accept a change to rime information. The resemblance in RT in rime-altered nonwords and original words further implied that listeners did show a high level of flexibility in processing rime, which permitted lexical activation to take place in a similar way in the absence of rime information as in the original word. In addition, this result showed that in nonwords, onset and tone were enough to produce priming effect and hence lexical activation.

On the other hand, rime-altered words gave no significant priming effect in either RT or ER with the word baseline as reference. It can also be seen that the rime-altered word was very close in RT and ER with its word baseline [1074 msec vs. 1075 msec; 20.78% vs. 21.02%]. This means that when a word with a different rime is heard, it was regarded as the word as it should be and the original word was not activated. Besides, a significant difference was found between the RTs in rime-altered words and in original words [31 msec in RT, $p < .01$; 5.23% in ER, $p < .005$]. This showed that altering rime in a word significantly lengthened the RT to the target. These results confirmed the essential role of rime in words.

There is an interaction effect between lexical status, onset and tone information, and there is also dominance of lexicality over sub-syllabic features. The lexicality effect was more obvious when we compared the RT and ER in rime-altered words and rime-altered nonwords. There were significant differences in both RT and ER between these two conditions [27 msec in RT, $p < .01$; 5.08% in ER, $p < .001$].

It is interesting to see that changes in two kinds of segmental information, onset and rime, produced a very similar pattern of results in the two experiments, that is, they gave significant priming effect in altered nonwords (Condition 3) but not in altered words (Condition 2). Two very clear conclusions can be drawn here. The first is that in nonwords, sub-syllabic features (or segmental information up to this point), governed lexical activation depending on the degree of overlapping or goodness-of-fit between the input and the lexical candidate to be activated. There is no all-or-none activation. In other words, lexical activation can still take place without one sub-syllabic feature. The second is that in words, lexical status eliminated the priming effect that two sub-syllabic features could produce. Result showed that onset-altered words did not differ significantly in RT with its word baseline, and so did rime-altered words. This meant that listeners would simply regard a word which had a different onset or rime as a different word from the original word. Listeners were sensitive enough to distinguish words with different onsets (or rimes) as two different words.

Given that these conclusions were drawn from segmental information, what would happen to a change in tone, a kind of suprasegmental information? Would the same pattern of results be produced and the same conclusions be drawn? What can we learn about the processing of tone if a same or different result pattern is produced? These are the main issues that we would address in Experiment 3.

Chapter 5 – Experiment 3

Hypothesis

In Experiment 3, we investigated the importance of tone in spoken recognition of Cantonese words. As found by Tsang and Hoosain (1979) and Cutler and Chen (1997), listeners had greater difficulty judging differences in tone as compared to differences in segmental information. Also, Tsang and Hoosain (1979) have found that listeners were equally good at judging vowel difference as in judging vowel plus tone difference. On the basis of these previous findings, we expected that listeners would have problems distinguishing two words sharing the same onset and rime but with different tones. This means that listeners would easily misprocess a word candidate with a different tone and regard it as the original word. We hypothesized that tone-altered primes (word or nonword) would give significant priming effect to their corresponding target words. If this hypothesis was not supported, then there should be no priming effect in both tone-altered conditions.

Method

Participants

Forty native Cantonese speakers (9 male and 31 female) were recruited. They were all students at the Chinese University of Hong Kong and were paid volunteers. None had reported any speech or hearing problems and none had taken part in Experiment 1 or 2.

Design

The two independent variables were word tone and lexical status. The dependent variables were the reaction time and the error percentage.

The five experimental conditions were as follows: Original word (Condition 1), tone-altered word (Condition 2), tone-altered nonword (Condition 3), word baseline (Condition 4), and nonword baseline (Condition 5).

Materials

The materials were constructed in a similar way as in Experiments 1 and 2. A pool of 45 monosyllabic word pairs and their associated targets was first constructed. They were constructed such that the member of each word pair shared the same onset, the same rime, but not the same tone with the other member. Again, the familiarity of the word pairs, and the associative strength between the words and their corresponding targets were checked. Twenty word pairs and their targets were finally chosen and formed the forty items in Conditions 1 and 2 (Appendix III). Forty more items were constructed for Condition 4.

Procedure

The procedures are as described in the General Methods section.

Results and Discussion

We have checked and deleted disyllabic homophones as in the previous two experiments. Thirty items were deleted and 170 items were left for analysis. The familiarity of the remaining words in Conditions 1, 2, and 4 was 1.58, 1.74, and 1.69 respectively (i.e. from very familiar to moderately familiar). No significant difference was found in word familiarity in Conditions 1, 2, and 4 [Conditions 1 and 2: $t(32) = -1.70, p > 0.05$; Conditions 1 and 4: $t(32) = -1.54, p > 0.05$; Conditions 2 and 4: $t(32) = 0.50, p > 0.05$]. The overall mean associative strength was 22.94% between primes and targets in Conditions 1 and 2.

Subsequently, 1546 errors (22.74%) out of the 6800 responses to test items were discarded and only RTs of correct responses were analyzed. Reaction times longer than 2000 msec and those exceeding two standard deviations below or above the mean reaction times were further discarded. The number of trimmed responses was 534 (7.85% of all responses).

Figures 5 and 6 showed the mean reaction times and mean error percentages of the five conditions respectively. Repeated measures ANOVA was conducted in similar way as in the previous experiments. We have adjusted the degrees of freedom with respect to the Greenhouse & Geisser (1959) epsilon (in RT only). Significant main effect of prime type was found in RT [$F(3.01,117.36) = 10.70, p < .001$] and error percentage [$F(4,156) = 5.10, p < .005$]. A power of 1.00 and 0.96 were calculated for RT and ER analyses respectively.

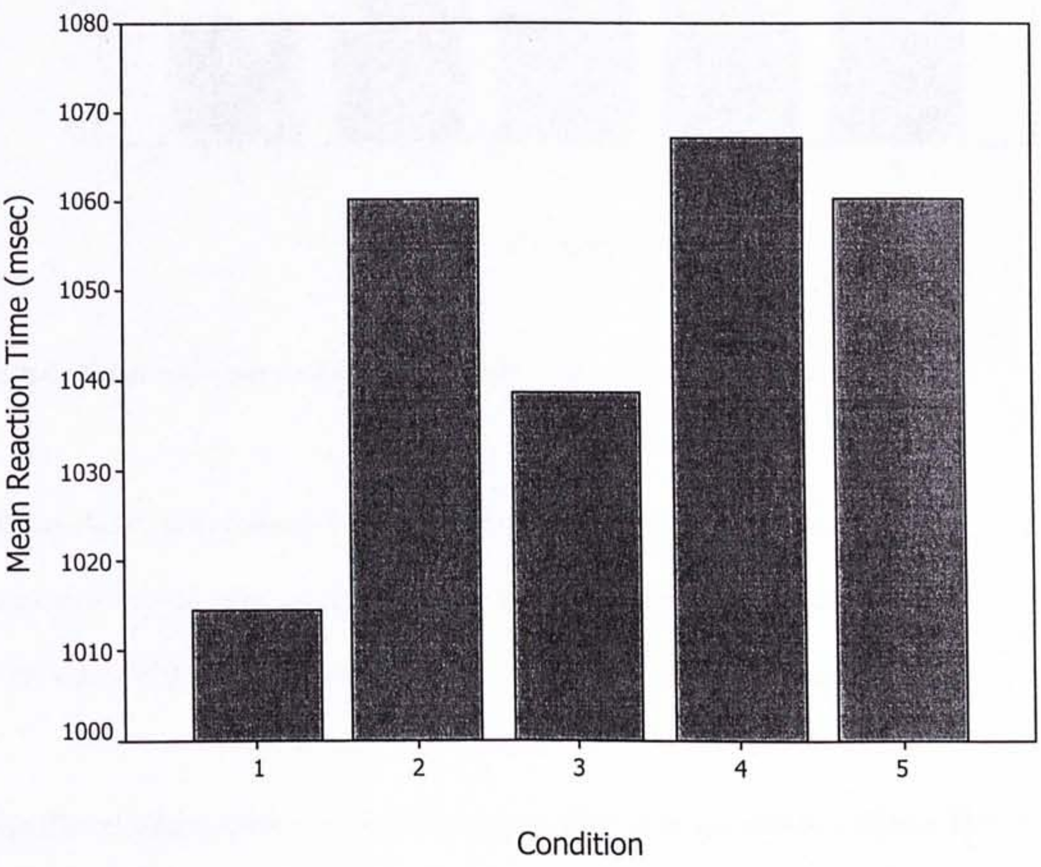

Figure 5. Mean reaction times in the five conditions in Experiment 3.

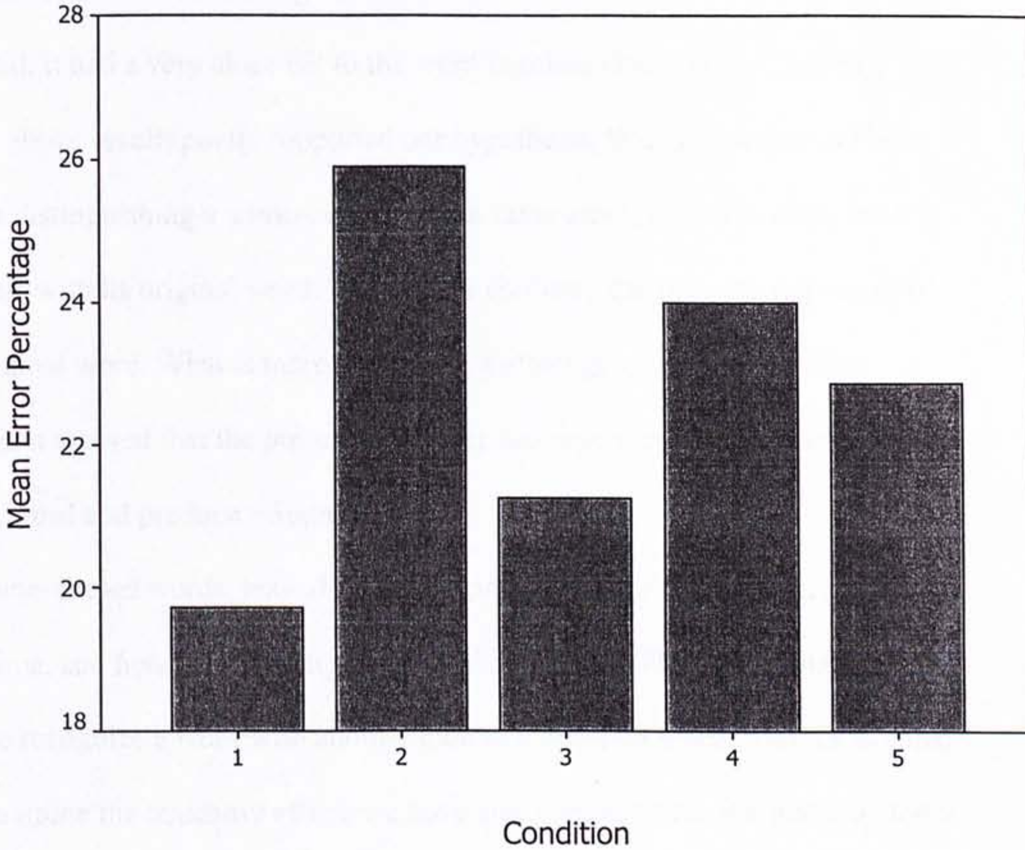

Figure 6. Mean error percentages in the five conditions in Experiment 3.

Newman-Keuls test showed that original words had a significant priming effect to their target words, with word baseline as reference [Priming effect: 52 msec, $p < .001$; 4.26%, $p < .05$]. It was also significantly faster than the remaining 4 conditions.

A significant priming effect was found in tone-altered nonwords (Condition 3) but not in tone-altered words (Condition 2). The tone-altered nonwords gave less than a half of the priming effect given by the original words [Priming effect: 21 msec, $p < .05$]. Besides, the priming effect of tone-altered nonwords was not accompanied with a significant difference in ER, which was different from that of onset-altered, or rime-altered nonwords, in which significant ER differences were found. On the other hand, tone-altered word was not significantly different in RT or ER with the word baseline. Still, it had a very close ER to the word baseline (25.88% vs. 23.97%).

The above results *partly* supported our hypothesis, that is, listeners did have difficulty in distinguishing a *nonword* having the same onset, the same rime, but a different tone with its original word. They easily confused the tone-altered nonword with the original word. What is more, the priming effect given by tone-altered nonword again showed that the presence of onset and rime was sufficient to activate the original word and produce priming effect.

In tone-altered words, lexical status has prevailed over the effect given by onset and rime, and hence no priming effect could be found. This meant that listeners were able to recognize a word with another tone as a different word from the original word. To examine the lexicality effect, we have also compared the RT given by tone-altered nonwords and that of tone-altered words. However, their difference was not so big as the difference between the altered word and the altered nonword conditions in previous two experiments. The tone-altered nonwords and tone-altered words did not differ significantly in RT, though the difference was close to significance level [21.42 msec, $p = 0.056$].

In addition, the role of tone was evident in both results of word and nonword conditions. We have found that tone-altered words had significantly longer RT and higher ER than original words [RT: 46 msec, $p < .001$; ER: 6.18%, $p < .001$]. This showed that altering tone of a word significantly delayed the reaction time to its target word. Also, the similar ER of tone-altered words and that of word baseline have shown the impact of tone in words. With regards to nonwords, it was reported above that the priming effect of tone-altered nonwords was less than a half of that of original words. This showed that a different tone in nonwords did reduce the activation to the original word and hence reduce the priming effect to a considerable extent.

Let us return to the question we have risen before, that is, what can we learn about the processing of tone, given the above results? The first is that a nonword with a different tone from the original word can produce lexical activation of the original word, like a nonword with a different onset or rime did. The second is that a word with a different tone was treated as a word different from the original word, like a word with a different onset or rime did. Lexicality has a consistent effect in affecting the processing of segmental information and that of tone information.

Chapter 6 – Comparison and Summary of the First Three Experiments

Having conducted the above three experiments, we asked further, is there any difference in the importance of the three features in activation of a word? As we re-examined the priming effect given by the altered nonword conditions (Condition 3), we saw that they varied in their size, that is, from 34 msec (onset-altered nonword), 49 msec (rime-altered nonword) to 21 msec (tone-altered nonword). They also differed in how they compared with the size of the priming effect of the original word condition. They ranged from being a half (onset-altered nonword), greater (rime-altered nonword), or less than a half (tone-altered nonword) of the priming effect of the original word (on condition that two baselines, word and nonword were used). Figure 7 and Table 1 showed the RTs of the three conditions and their corresponding baselines. In the following, we have made a comparison of the RTs of these three conditions statistically.

A Comparison Across the First Three Experiments

We analyzed whether there was any significant difference among the altered nonword conditions across the three experiments. A one-way analysis of covariance was performed on RTs of the altered nonword conditions. The dependent variable was the RT of altered nonword conditions. The RT of nonword baseline was chosen as a covariate because we expected that it would relate to the RT of altered nonword conditions. The RT of nonword baseline was shown to provide significant adjustment to the DV (i.e., RT of altered nonword conditions) [$F(1,116) = 556.38$, $p < 0.001$]. After adjustment by the covariate, it was found that the RT in different altered nonword conditions did not vary across the three experiments [$F(2,116) = 1.67$, $p = 0.19$].

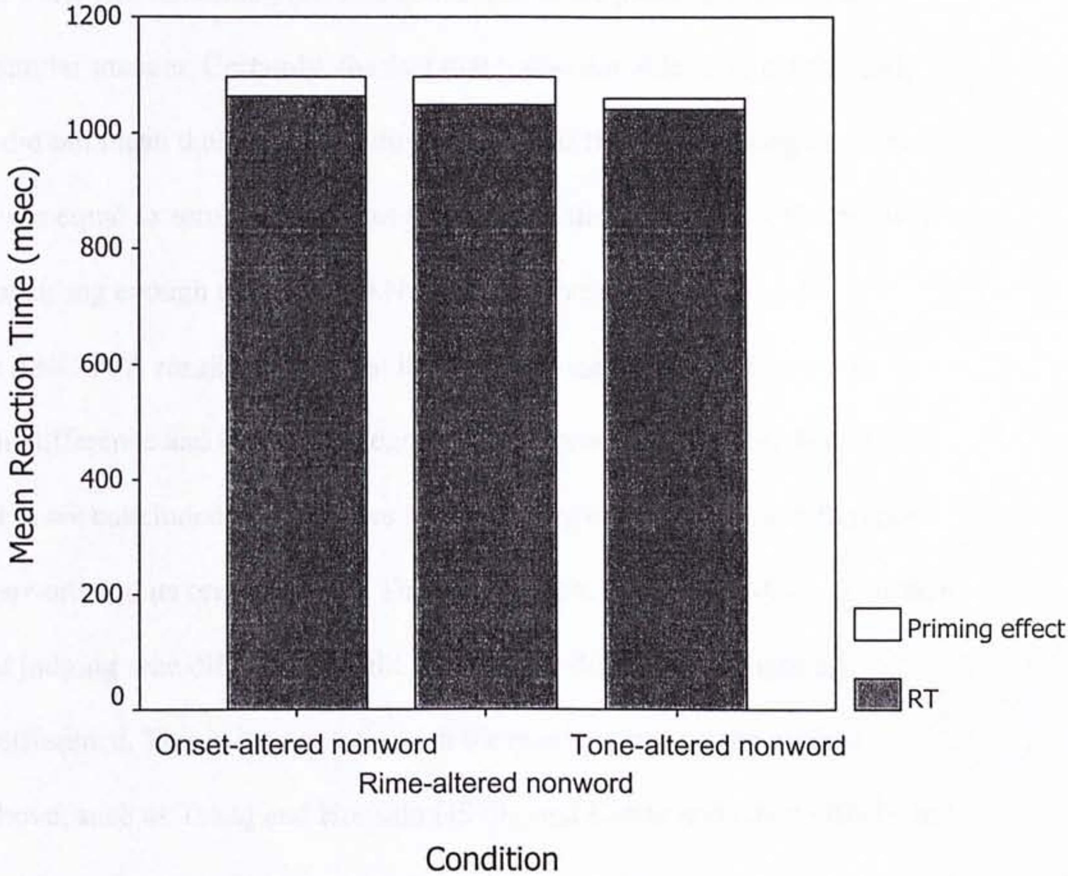

Figure 7. Mean reaction times and priming effects of nonword conditions of Experiments 1, 2, and 3.

Table 1. Net priming effect of nonword conditions in Experiments 1, 2, and 3

Expt	Condition	RT	Baseline	Priming effect	*p*-valu
1	Onset-altered nonword	1063 msec	1097 msec	34 msec	0.00
2	Rime-altered nonword	1046 msec	1095 msec	49 msec	< 0.00
3	Tone-altered nonword	1039 msec	1060 msec	21 msec	0.02

The fact that no significant result was obtained in ANCOVA tells us that there was no reliable difference between onset-rime, rime-tone, or onset-tone combination on lexical activation. In other words, whenever onset, rime, or tone is missing, the other two remaining features contribute to the priming effect in a somewhat similar manner. Certainly, the fact that it was not able to reject the null hypothesis did not mean that the probability of having differences among the three conditions was equal to zero. However, as a minimum, their difference, if there was any, was not strong enough to pass the ANCOVA to give significant results.

The ANCOVA result showed that there was no significant difference in judging tone difference and in judging segmental difference. Remember that in Experiment 3, we concluded that listeners had difficulty in judging tone difference between nonword and its original word. The insignificant result in ANCOVA further implied that judging tone difference might *not* be more difficult than judging segmental difference. This is inconsistent with the results given by the studies reviewed above, such as Tsang and Hoosain (1979), and Cutler and Chen (1997), in which processing tone information was found to be more difficult than processing segmental information.

Studies on speech errors have provided converging evidence that tone can be processed similarly as segmental information. For instance, Gandour (1977) has shown that tone errors in Thai can be explained in the same principles as segmental errors. A study of slips of the tongue in Mandarin by Shen (1993) has also reported the similarity between tone errors and segmental errors. Besides, neurological data have provided similar evidence. For instance, Packard (1986) studied Chinese aphasics with unilateral left-sided lesion and found that their deficits in producing tones was the same as in producing consonants in terms of severity and type.

In the present study, the main conclusion that we could achieve is that two sub-syllabic features sufficed to produce lexical activation. However, the underlying mechanism of how lexical activation is produced is unclear. For instance, we are not sure if the two sub-syllabic features co-operated or worked individually. However, past research in Cantonese did report significant interaction between onset, vowel, and tone. For instance, Lee (1993) has conducted a study on the interaction between tone and vowel. He has noted that vowels in Entering tones (the tones which end with /p/, /t/, or /k/, according to the traditional Cantonese tone classification) are shorter than those in non-Entering tones. Besides, the high Entering tone occurs with the four short, lax vowels only, while the mid Entering tone occurs with the seven long, tense vowels only. Hombert, Ohala and Ewan (1979) has also mentioned that high tones tend to occur in syllables which had earlier prevocalic voiceless consonants, while low tones tend to occur in syllables which had earlier prevocalic voiced consonants. It was found that fundamental frequency was higher after voiceless stops than after voiced stops. Similarly, research in English (e.g. Kessler et al., 1997, Treiman et al., 2003) has shown significant connections between consonant and vowel in perception and production. On the contrary, there are also studies, such as the study of Mandarin by Shen (1993), which showed that tone and segmental information are represented and processed separately.

Summary of the First Three Experiments

An overview of the three experiments reported above showed that all altered nonword conditions (Condition 3) gave significant priming effect. It can be seen that in nonwords, altering either onset, rime, or tone could still promote the recognition process. In other words, any two available sub-syllabic features are sufficient to facilitate the recognition process. Missing any one feature was not devastating and did not prevent recognition. Instead, the remaining features still supported the recognition process. This finding is consistent with a study done by Chen and Yip (2001). Chen and Yip (2001) had their participants made same-different judgments on two syllables along a specific dimension, that is, onset, rime, tone, or the whole syllable. The participants were asked to judge whether two syllables were the same in onset, rime, tone, or the whole syllable according to the instruction they were given. Results showed that in judging any one dimension, the other two dimensions had a significant impact on the judgment. For instance, participants were faster to judge whether two syllables were the same in onset when rime and tone were the same, then when rime and tone were different.

Our finding has two implications in understanding of the recognition process. First, it revealed the flexibility of recognition system that listeners possess. It is different from the directional view, which proposes that the presence of onset is a must in lexical activation. Instead, it is close to the view that recognition system can tolerate variabilities in speech so that words can be recognized even with an imperfect input. Second, the priming effect found in altered nonwords showed that Cantonese listeners are aware and sensitive to sublexical level of representation. This is noteworthy in Cantonese listeners, for most of them learn Cantonese in a syllable-by-syllable manner, and knowledge of sub-syllabic structures like onset and rime is usually not necessary. In addition, given the fact that the listeners should seldom encounter nonwords in normal conversation, the consistent priming effect shown in all three altered nonword conditions clearly did not result by chance.

While we acknowledged the importance of sub-syllabic features in lexical activation, the consistent lexicality effect showed that this is overridden by the strong influence of lexical status. Lexicality has a decisive role in determining the impact given by onset, rime, and tone.

Chapter 7 – Experiment 4

After conducting these three experiments, two questions still remain to be resolved. First, what is the contribution of each individual sub-syllabic feature in lexical activation? Is there any difference in priming effect when one or two features are present? Second, given the insignificant result in ANCOVA, we were not assured if there is or is not difference in processing tone and segmental information. What would happen if we compare the priming effect of onset, rime, and tone directly? Experiment 4 was devised to address these questions.

Hypothesis

In the previous three experiments, we have learnt that lexical activation could still proceed in the absence of one sub-syllabic feature. By now we could be certain that two aspects of information suffice to produce activation. However, the contribution of each aspect is still not clear. We decided to conduct another experiment, in which three nonword conditions were included, and only one feature was kept unchanged in each condition. In this way, the contribution given by each feature can be isolated and compared. We hypothesized that if only one feature was sufficient to produce lexical activation, then significant priming effect should be observed in one or more nonword conditions. However, if this hypothesis was not supported, then there should be no significant priming effect in these conditions.

Method

Participants

Forty native Cantonese speakers (22 male and 18 female) were recruited. They were all students at the Chinese University of Hong Kong. Eighteen of them were paid volunteers, and the remaining took part in the experiment as a laboratory requirement for credit in an introductory psychology course. None had reported any speech or hearing problems and none had taken part in the previous experiments.

Design

In the previous experiments, we have altered one of the three features, onset, rime or tone to see their impact on word recognition. In Experiment 4, instead, we have kept one of the three features, onset, rime, or tone unchanged. Six experimental conditions were therefore constructed as follows: Original word (Condition1), same-onset nonword (Condition 2), same-rime nonword (Condition 3), same-tone nonword (Condition 4), word baseline (Condition 5), nonword baseline (Condition 6).

Materials

The materials were chosen from the previous 3 experiments. Forty word primes and their corresponding targets were selected for Condition 1. Forty more word primes were chosen which served as the word baseline (Condition 5). The mean word familiarity of Conditions 1 and 5 were 1.51 and 1.60 respectively (i.e. from very familiar to moderately familiar). They had no significant difference [$t(38) = -1.40, p > 0.05$]. The overall mean associative strength between primes and targets in Condition 1 was 25.33%.

For Conditions 2, 3, and 4, forty nonword items were constructed for each condition by altering any two of the three features, onset, rime, or tone (Appendix IV). Also, forty nonword items were constructed for Condition 6 to serve as a nonword baseline. There was a total of 240 test items (the carrier compound words were not shown in Appendix IV). Also, an equal number of filler items with nonword targets were constructed such that there was a total of 480 items, which were further divided into 6 blocks. The stimulus arrangement in Experiment 4 was shown in Appendix VI. In each block, there were 40 test items and 40 filler items. The stimulus allocation in each block was also shown in Appendix VI. The target of the test items appeared only once in each block. Besides, the trials were randomized in each block. The participants were presented with the stimulus in similar way as in the previous three experiments. Breaks were given in-between each block. Besides, since there were too many items in each block (80 items), we insert a break in the middle of each block. Twelve practice items, which were the same as those in the previous experiments, were given in prior to the test trials.

Procedure

The procedures are described in the General Methods section.

Results and Discussion

Before the analysis, it was found that there were certain items in which all subjects have given incorrect responses. They were generated because of the error made in running the experiment. These items were therefore discarded and excluded from our analysis. The number of items left for analysis in each condition were 16 (Condition 1), 26 (Condition 2), 31 (Condition 3), 17 (Condition 4), 24 (Condition 5), and 21 (Condition 6). Afterwards, any remaining incorrect responses were discarded and only correct RTs were analyzed. There were 477 errors (8.83%) out of the 5400 responses to test items. Reaction times longer than 2000 msec and those exceeding 2 standard deviations below or above the mean reaction times were further discarded. The number of trimmed responses was 612 (0.11% of all responses).

Figures 8 and 9 showed the mean reaction times and the mean error percentages of the six conditions. Repeated measures ANOVA has shown a significant priming effect of prime type in RT [$F(5,195) = 11.29, p < .001$] and error percentage [$F(5,195) = 8.63, p < .001$]. A power of 1.00 was achieved for both RT and ER analyses.

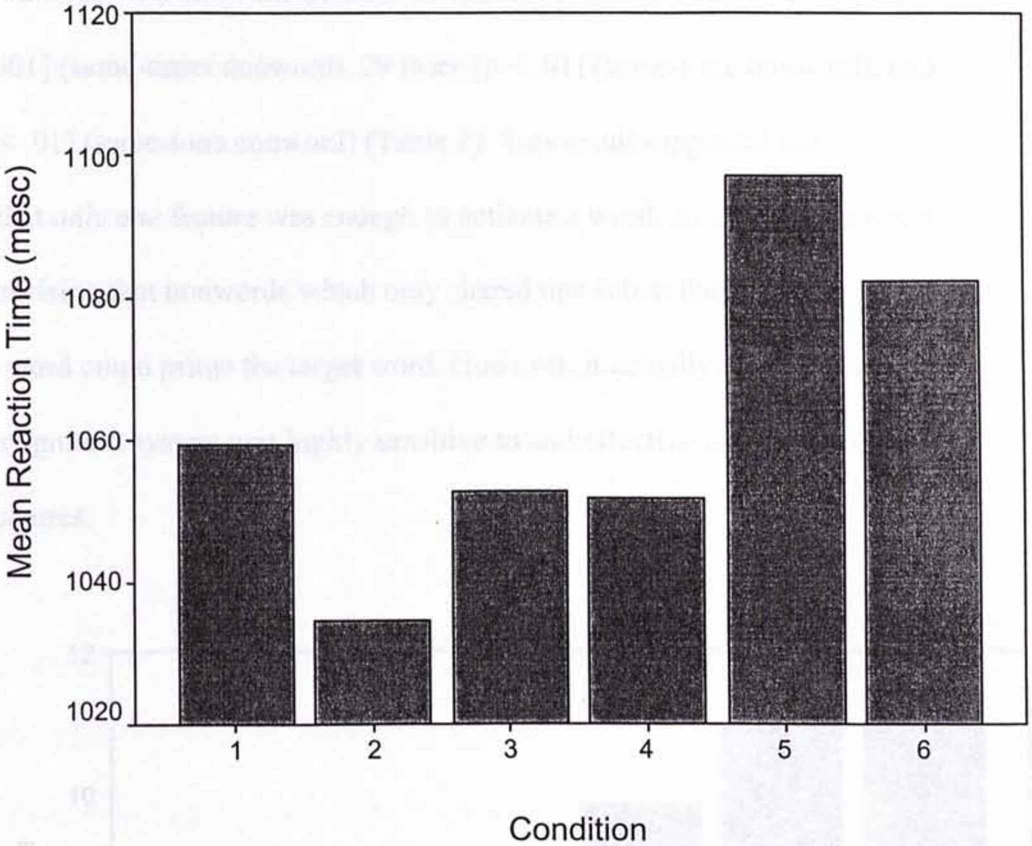

Figure 8. Mean reaction times in the six conditions in Experiment 4.

Newman-Keuls test showed that the original word condition had a significant priming effect [Priming effect: 38 msec in RT, $p < .001$; 7.03% in ER, $p < .001$] with word baseline as reference. Besides, significant priming effects were found in all

Table 2. Net priming effect of nonword conditions in Experiment 4

Expt	Condition	RT	Baseline	Priming effect	p-valu
4	Same-onset nonword	1035 msec	1082 msec	47 msec	< 0.00
	Same-rime nonword	1053 msec		29 msec	0.006
	Same-tone nonword	1052 msec		30 msec	0.008

nonword conditions with nonword baseline as reference. The priming effects were 47 msec [$p < .001$] (same-onset nonword), 29 msec [$p < .01$] (same-rime nonword), and 30 msec [$p < .01$] (same-tone nonword) (Table 2). This result supported our hypothesis that *only one* feature was enough to activate a word. At the first glance, it might be surprising that nonwords which only shared one sub-syllabic feature with the original word could prime the target word. However, it actually revealed that listeners' recognition system was highly sensitive to and effective in processing sub-syllabic structures.

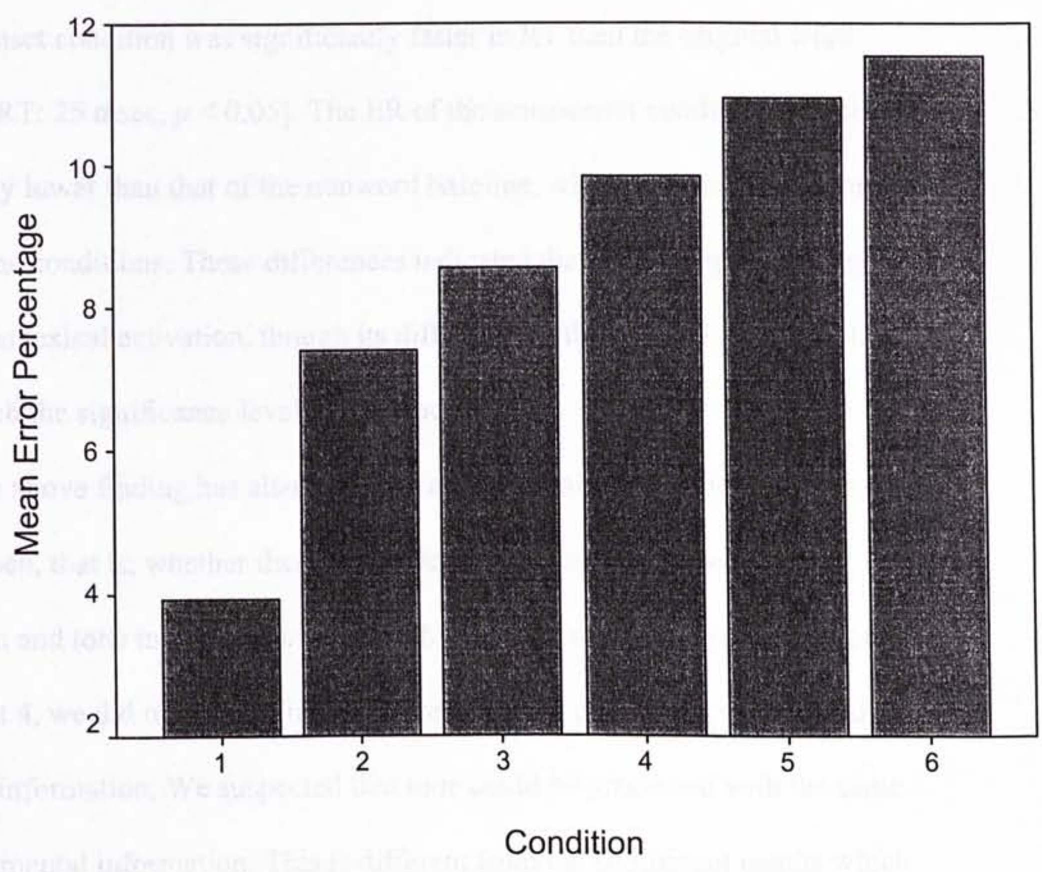

Figure 9. Mean error percentages in the six conditions in Experiment 4.

The post-hoc test also showed that there was no significant difference in RTs among the three features. This echoed with the result of ANCOVA, which showed that there was no significant difference among the RTs of the three altered nonword conditions. It showed that the three sub-syllabic features might not differ in their weight in lexical activation. This finding has provided a possible answer to the debate on the significance of onset. From the present results, we might conclude that onset is not more or less important when compared with rime and tone. This argues against the special status of onset in lexical activation. Caution should be taken, however, that there is a trend that onset produced a greater priming effect (47 msec) than rime (29 msec) and tone (30 msec) did. Besides, among the three features, only the same-onset condition was significantly faster in RT than the original word condition [RT: 25 msec, $p < 0.05$]. The ER of the same-onset condition was also significantly lower than that of the nonword baseline, which was not so in same-rime or same-tone conditions. These differences indicated that onset might have a greater influence on lexical activation, though its difference with rime and tone might not be able to reach the significance level in our study.

The above finding has also provided a clue to answer another question that we have risen, that is, whether there is a difference in processing segmental information and tone information. From both the result of ANCOVA and that of Experiment 4, we did not find reliable difference in the processing of tone and segmental information. We suspected that tone could be processed with the same ease as segmental information. This is different from the significant results which were found in the past research that we have reviewed in Introduction.

Chapter 8 – General Discussion

What Can We Learn about Spoken Word Recognition In Cantonese

Altogether, this study has shown clear evidence that sub-syllabic features are important to spoken word recognition in Cantonese. To be more specific, we have found that in *nonwords*, when only one of the three sub-syllabic features, onset, rime, or tone, was available, lexical activation of a word could take place. What is more, we did not find any statistically significant difference in contributions of each feature to lexical activation. This suggested that the ease of processing segmental information and tone information could be similar. On the other hand, the consistent lexicality effect in the first three experiment showed that lexical status was a crucial factor in lexical activation. No lexical activation of a word could be produced when any one feature of this word was changed. This reflects how Chinese listeners process spoken words in normal circumstances.

How the Contemporary Models Accommodate Our Findings

Given that the present study was conducted in Cantonese, a dialect which has been studied far less than English and other Indo-European languages, we have to generalize the present findings to the global picture of human spoken word recognition. For this reason, we have chosen four models of spoken word recognition, that is, COHORT I (Marslen-Wilson & Welsh, 1978), COHORT II (Marslen-Wilson, 1987), TRACE (McClelland & Elman, 1986), and SHORTLIST (Norris, 1994) to see how they can accommodate the present findings. In fact there are still many models apart from these four models. We have chosen only these four models because they were referred to and compared frequently by reviewers (e.g., Frauenfelder,1996; Frauenfelder & Peeters, 1998; Cleary & Pisoni, 2001; Jusczyk & Luce, 2002). A brief review on the four models was presented as follows, followed by the predictions on the present experiments by each model. Finally, we concluded which model was the best-fit model of the present findings.

Overview of Models of Spoken Word Recognition. The four models mentioned here ranged from verbal models, including COHORT I and II, to computer-implemented models, including TRACE and SHORTLIST. The COHORT models (Marslen-Wilson, 1987; Marslen-Wilson & Welsh, 1978) assume that only the words in the mental lexicon which match the target word with onset, namely the *word initial cohort*, would be activated. As more and more speech input is heard, the cohort members which mismatch later incoming sensory information drop out of the cohort. The recognition point is reached when the target word is unique compared with the other members in the cohort. Recognition of the target is affected merely by the presence of cohort members. The cohort members have no direct influence on the target word and its activation level. The basic frameworks of COHORT I and II are similar. The difference between the two versions is that in COHORT I model, the cohort membership is mainly determined by the sensory information, and the matching process is an all-or-none process. In COHORT II model, the activation level of cohort members depends on their match with the input and also their word frequency. COHORT II model allows words that mismatch the sensory input to some minimal but unspecified degree to enter into the cohort. Besides, COHORT II assumes that there is a direct mapping of the input onto the lexical representation and rejects the presence of sublexical level of representation.

The TRACE model (McClelland & Elman, 1986) is an interactive activation model which consists of a very large number of units organized into three levels, the feature, phoneme, and word levels. Each level has its corresponding detectors, namely feature detectors, phoneme detectors and word detectors. There are facilitatory connections between units across different levels (feature-phoneme, phoneme-word, and word-phoneme) and inhibitory connections among units at the same levels (feature-feature, phoneme-phoneme, and word-word). All connections are bi-directional. When speech input is heard, the feature units are first activated, which then activate the phoneme units which match the activated features. The activated phoneme units in turn activate the words which contain them. The activated words then inhibit each other and excite the phonemes that they contain. These processing units continue to interact, and the activations are updated over time. Word frequency effects are incorporated in the different resting activation level of word units and in the different strengths of phoneme-word connections.

The SHORTLIST model (Norris, 1994) consists of two processing stages. In the first stage, a "shortlist" consisting of word candidates which match the input is produced with bottom-up excitation and inhibition. This is achieved by an exhaustive search through the mental lexicon. The word candidates included in the shortlist are those which match with the input, regardless of their alignment. In the second stage, the word candidates are wired into an interactive activation network as assumed by the TRACE model and lateral inhibition occurs among the candidates. The number of candidates in the network is limited to 30 in the simulations done by Norris (1994). As more speech input is available, the candidates with low bottom-up activation drop out of the shortlist to make room for the candidates with higher activation. The SHORTLIST model resembles the TRACE model in that they involve a lexical competition network. However, they are also different in some ways. A major difference between the two models is that, while the TRACE model emphasizes the top-down feedback from the lexical level to the phoneme level, there is no such lexical feedback in the SHORTLIST model.

The models mentioned above have different predictions on what lexical candidates are activated when a speech input is heard. In the following, we would illustrate what are the expected results that the four models would predict for our experiments and explain why they make such predictions.

Predictions of Recognition Models on Experiment 1. A list of predictions made by each model for word and nonword input is shown in Appendix VII. As an example, we have chosen three different inputs, that is, *bing1* (the original word), *sing1* (onset-altered word), and *kwing1* (onset-altered nonword) to illustrate how they activate the lexical candidate *bing1* as predicted by the four models. It is obvious that all models predict that the input *bing1* would activate the lexical candidate which is its exact match, that is, *bing1*. However, they disagree on whether such lexical activation would occur given an onset-altered word or an onset-altered nonword. For onset-altered word (i.e., *sing1*), COHORT I predict that only the cohort members are activated, and so onset-altered word would not be activated. It is less clear in COHORT II model because it allows words that do not fully match the input to a certain degree to enter the cohort. The definition of competitor set is not so clearly stated (Frauenfelder, 1996) and an exact prediction cannot be made for onset-altered words. For TRACE model, by definition, it allowed mismatching candidates to be activated, because phonemes which are different from the input minimally are activated and so are the words that contain them. However, since these mismatching lexical candidates were strongly inhibited by the matching target word, they would not be activated in reality. This is confirmed in the TRACE simulation by Frauenfelder and Peeters (1998). The TRACE model in fact predicts that only the cohort members are activated for onset-altered words like the COHORT I does. The SHORTLIST model predicts that any mismatching candidate are excluded from the shortlist, and hence the onset-altered word is not activated.

For onset-altered nonwords, COHORT I and II make predictions in the same way as they do for onset-altered words. The TRACE model predicts in a different way that *bing1* can be activated by onset-altered nonwords. It predicts differently for onset-altered word condition and nonword condition because in the latter condition, there is no lateral inhibition from the word level which prevent the mismatching lexical candidate from being activated. The SHORTLIST model is not affected by the lexical status of input in predicting which lexical candidate is activated, and so it predicts no activation for onset-altered nonword.

Predictions of Recognition Models on Experiment 2. In Appendix VII, we have also worked out the predictions made by the four models on Experiment 2. We have selected another word, *baau1*, as the lexical candidate to be activated. Three different inputs, that is, *baau1* (the original word), *biu1* (the rime-altered word), and *boe1* (the rime-altered nonword) are investigated. The input *baau1* activates the candidate *baau1* as predicted by the four models. By definition, COHORT I and II models predict that rime-altered word (*biu1*) and rime-altered nonword (*boe1*) would activate *baau1* in the beginning, as it matches the input with the onset /b/. However, as later incoming mismatching input is received, these activated candidates are quickly deactivated. This is consistent with the findings provided by Zwitserlood (1989) and Frauenfelder, Scholten, and Content (2001). Zwitserlood (1989) presented auditory primes like *capti* which is derived from the word *captive*, followed by a target word. He found that the semantic associate of the mismatching word candidate *captain* was no longer primed. What is more, Frauenfelder et al. (2001) has conducted two phoneme monitoring experiments. They found that there was no difference in the monitoring latencies of a target phoneme /r/ in nonwords like *satobunaire*, in which the mismatching phoneme was at the initial position, and in nonwords like *vocabunaire*, in which the mismatching phoneme was at a later position. This showed that the lexical candidate was deactivated immediately by any mismatching phoneme.

In TRACE, we might expect that it would predict activation of mismatching candidates *biu1* and *boe1*. However, due to the strong inhibition of the matching target word *baau1*, the activation of mismatching candidates are quickly suppressed. TRACE model again predicts differently for rime-altered word and rime-altered nonword. As there is no lateral inhibition at the word level for nonwords, the rime-altered nonword is expected to be activated. The SHORTLIST model, which includes bottom-up inhibition, predicts in a similar way as COHORT models that rime-altered word and nonword cannot enter the shortlist and hence not be activated.

Which is the Best-Fit Model of the Present Findings? At this point we did not make any predictions for Experiments 3 and 4 because they involve the manipulation of tone, a feature which is not explicitly explained in the four models mentioned above. We concluded here what is the best-fit model which can accommodate the results of the first two experiments. We can see that the dissimilar results given by the altered word and altered nonword conditions coincided with the predictions made by the TRACE model. Provided that the predictions of the TRACE model were correct, the strong inhibition from the word level (i.e., from the altered word) would reduce the activation of its competitor (i.e., the original word), and it in turns make priming impossible. On the other hand, in altered nonword, there would be no such inhibition from word level. Any bottom-up information could activate the original word, which in turns lead to successful priming.

The above comparison of predictions made by the different models has assigned a further important meaning to our findings, apart from understanding the role of sub-syllabic features on spoken word recognition in Cantonese, which is the original objective of our study. That is, it leads us to consider which is a suitable theoretical framework of spoken Cantonese (or Chinese) and a universal model of spoken word recognition. Given the fact that Chinese language users comprise about one-fifth of the global population, Chinese language has not been given its deserved weight in empirical research. Most research on spoken word recognition has been done on English and Indo-European languages, and little has been done on Chinese language. The lack of available data and theories in word recognition of spoken Chinese poses a serious problem for cognitive researchers in constructing a general theory of spoken word recognition. Chinese language has its unique and important features, such as tone, which make it distinct from other languages. It is a challenge of how to construct a universal model which can capture the different features of different languages. Inevitably, future researchers need to take a long road and much more research is needed until a suitable model of spoken word recognition can be constructed.

We can see that the above comparison has a fundamental limitation, that is, it does not include the findings in Experiments 3 and 4, in which tone is manipulated. Although prosodic information is not addressed in detail in the four recognition models mentioned here, it is not entirely neglected. An example is the Metrical Segmentation Strategy, which is incorporated in the modified version of SHORTLIST model. It states that word candidates which is aligned at their onset with a strong initial syllable with the input are more activated than those which are not. What is more, a study by Ye and Connine (1999) have tried to incorporate tone information in TRACE model. They proposed a modified version of TRACE model, assuming that tone information is a separate level of representation in speech processing. They proposed that tone was a phoneme which was like any segmental features, onset and rime. They assumed that *toneme*, similar to phoneme in TRACE model, is activated depending on the input signal and the feedback from the lexicon. Ye and Connine (1999)'s suggestion might help us explain why altering tone (Experiment 3) gave a similar pattern of priming effect like altering onset (Experiment 1) or rime (Experiment 2).

Comparison of Present Study with Past Research

Another issue that is worth mentioning here is what are the differences of this study with past research and what are the new insights we have introduced. There are three important differences compared with past Chinese research. First, in the present study we verified our findings in spoken Chinese with the contemporary spoken word recognition models. This acts as an exploratory step of linking spoken Chinese research to the general picture of spoken word recognition, which has not been tried before in previous Chinese research. Second, in this study we have successfully shown and compared the contribution of each sub-syllabic feature. The contribution of each feature has been quantified by the size of priming effect. This is a direct measure of comparison that other studies have not provided. Third, in this study, we have a clear picture of how lexicality is dominant over sub-syllabic features. In contrast, past Chinese research has not dealt with the interaction between lexical status and sub-syllabic features directly.

There are also two major differences in the results of the present study and that of the past research on spoken word recognition. One of the differences lies in the different results found regarding the processing of segmental and tone information. As reported in the previous sections, we could not find significant difference in the lexical activation provided by word onset, rime, and tone in ANCOVA analysis and in Experiment 4. On the contrary, in the past research reviewed in Introduction (Cutler & Chen, 1997; Ye & Connine, 1999), tone information was found to be processed less efficiently than did segmental information. It is unclear why such a discrepancy appears. We suspected that it might be due to the different paradigms employed in the present study and in the past studies. The paradigms employed by past researchers (Cutler & Chen, 1997; Ye & Connine, 1999) include lexical decision, syllable comparison, and tone-vowel detection, while in the present study, we have used the auditory-auditory lexical decision priming task. What is more, we suspected that it could also be explained by the different stages of processing examined by the past research and the present study. As claimed by Cutler and Chen (1997), the slower response to tone than segmental information might be because their experiments examined spoken word processing at a simple perceptual level. On the contrary, the present experiments examined processing during lexical access, which is a deeper level of processing. If it was the case, then it might reveal the different stages involved in processing tone information. This warrants further investigation before we could draw a conclusion.

The second difference with some of the past recognition research is that the present study did not support the directional view on the status of word onset in spoken word activation. The present findings inclined to support that overall goodness-of-fit of speech input and lexical representation is more important in word activation. This is closer to the current view that *strictly* directional view on word onset cannot accommodate many findings which did not opt for the necessity of complete word onset information in spoken word processing (Connine et al., 1993; Connine et al., 1994; Slowiaczek et al., 1987).

Limitations and Improvements

Despite the advancements made by the present study, we have found several limitations which posed problems in accounting for our results. First of all, the role of two sub-syllabic features and that of one feature have been studied separately in two sets of experiments (the first three experiments and Experiment 4), which have employed different designs and stimulus arrangements. The reason why we have used separate experiments instead of only one is to avoid that there might be too many conditions in one experiment, which would probably make it too clumsy for analysis. However, this created a problem that we could not compare directly the contribution of two features and that of one feature by contrasting the first three experiments with Experiment 4. If we *were* able to compare two features and one feature directly, then we could know if there were any interactions or co-operations, say, additive or inhibitory effects, between two features. We suggested that future researchers might do follow-up study including two-feature altered nonword conditions and one-feature altered nonword conditions in one experiment. This could probably show how two features interact to produce priming effect.

Second, in the present study, we have chosen a 500-ms ISI between the prime and the target. It is obvious that lexical activation of a lexical candidate and its priming effect would decrease over time. Therefore, the priming effect obtained in our experiments should have a close relation with the particular ISI we have chosen. What would happen if we shortened the prime-target ISI? Would priming effect also be observed in altered word conditions? We have not included several ISIs in this study to avoid making the design too complicated. Nonetheless, future researchers could manipulate the duration of prime-target ISI to see how it affects lexical activation. Besides, we suggested that the present study could also be replicated using the cross-modal priming task, say, an auditory-visual priming lexical decision. This is because in cross-modal priming, the ISI can be controlled more flexibly. For instance, the target could be presented either during the presentation of the prime, or a certain time interval after the prime.

The third limitation lies in the construction of materials in the present study. To make sure that the prime is the one that we have chosen but not its neighboring homophone, we have added a carrier compound word before the prime. We were not sure what influence it has made on the priming effect. For instance, the difficulty level of the carrier compound word, and the association of the carrier compound word and the prime might affect the priming effect. The RT of this study ranged from 1010 msec to 1110 msec, which was longer than that in similar previous research (e.g., the RT of Milberg et al. ranged from 650 msec to 850 msec). This showed that time was needed for listeners to process the carrier compound word. A modification we could make is that, before the experiment, we could present a whole list of primes, together with their carrier compound words to the participants. This could make sure that participants were familiarized with the primes. Subsequently, during the experiment, participants could be presented with the primes only, without the preceding compound word. In this way, we could get rid of the possible confounding that the carrier compound word might have made.

The final limitation is related to tone neighborhood density. In Cantonese, words can be different in the number of tone neighbors that they can have. For instance, in Experiment 3 (Appendix III), the word *dou1* have 4 homophones which share the same tone (including Tone 1), while the word *fo1* have 3 homophones sharing the same tone (including Tone 1). The different tone neighborhood density of items made it more complicated to account for the lexical activation that the original word and the tone-altered conditions have produced. There might be possibility that a word with a low tone neighborhood density (i.e., with less tone neighbors) could give a stronger priming effect to the target word. A solution we could provide is that we might control the number of tone neighbors that the prime words could have. However, it might bring a potential cost that it becomes too demanding for constructing the materials.

Further Studies

In the last part of this paper, we would suggest some future directions that researchers might follow in studying spoken word recognition. In the first place, there is still room for investigating whether there are any differences in processing segmental information and tone information. In the present study, we obtained insignificant results in ANCOVA and in the comparison of the three nonword conditions in Experiment 4. We deduced from this insignificant result that there might be no difference in the difficulty level of processing segmental (i.e., onset and rime) and tone information. However, this conclusion was based on negative evidence and so we could not deny that potential difference might exist. A more ingenious design is needed to provide positive evidence on this problem.

Second, in the first three experiments, we have found the dissimilar results given by the altered word and the altered nonword conditions and concluded that TRACE model is the best-fit model of our findings. This conclusion is based on the assumption of lateral inhibition at lexical level in the TRACE model. Therefore, there is a potential risk that this conclusion might not be valid if the assumptions of the model were not valid. As mentioned in Frauenfelder and Peeters (1998), computational models like TRACE are constructed depending on a number of factors such as the definition of features, the use of phoneme level and the parameter setting of the model. There are in fact debates on whether some activation flows as proposed in recognition models do exist. For instance, it is still under debate whether top-down lexical feedback (i.e., word-to-phoneme activation) does exist in TRACE. In the simulation study by Frauenfelder and Peeters (1998), it was found that word recognition was not necessarily speeded up by top-down lexical feedback, but instead hindered by it sometimes. A more recent study by Norris, McQueen, and Cutler (2000) have made a similar argument that lexical feedback could not possibly improve word recognition, and that it could sometimes improve phoneme identification but sometimes impair it. To verify if these activation flows do exist in computational models, Chinese language is a good means for study. For instance, computer simulations can be done with spoken Chinese. Researchers might also manipulate spoken Chinese words at a lower level such as phonemic or featural level to verify the presence of activation flows proposed. However, the problem of how to incorporate tone in computer simulations obviously needs to be solved.

Lastly, there is a problem of how words are represented in the mental lexicon. There are two opposing views on this issue, one is the *mediated lexical access models*, and the other is the *direct access models*. Mediated lexical access models propose that there are intermediate levels of representation between sensory input and lexical representation. They include computational models like TRACE and SHORTLIST. In contrast, direct access models propose that sensory input is directly mapped onto the lexical representation. In these models, there are no intermediate levels of representation like features or phonemes. For instance, Warren and Marslen-Wilson (1987), using a gating task, found inconsistent results of mapping of input onto phonemes. McLennan, Luce, and Luce (2003) have studied the same issue using flapped words. They found that if ambiguous speech input was heard or if time was available, underlying (or intermediate) representations became dominant. If speech input was unambiguous, or if time was not enough, surface representations became dominant. This problem of how words are represented in mental lexicon is crucial in our study because we focused on sub-syllabic level of representation. This assumed that underlying representations mediated the mapping of the speech input onto the lexical representation. However, if indeed no intermediate representations *were* needed in the mapping process as assumed by direct access models, we have to re-interpret all the findings obtained in the present study. We proposed a method here how to prove the existence of sublexical representation in the mapping of input onto Cantonese words. As reviewed in Introduction, there were not much psycholinguistic research which has supported a particular syllable structure in Cantonese like the onset-rime structure in English. Future researchers could conduct experiments or statistical studies like the series of studies done by Treiman and her associates (De Cara & Goswami, 2002; Fowler et al., 1993; Kessler & Treiman, 1997; Treiman, 1986; 1988; Treiman, Fowler, Gross, Berch, & Weatherston, 1995; Treiman & Kessler, 1995) to see if there is a particular syllable structure in Cantonese. The presence of a particular syllable structure in Cantonese could provide support for the presence of intermediate representations in the mapping process.

References

Chen, H.-C., & Cutler, A. (1997). Auditory priming in spoken and printed word recognition. In H.-C. Chen (Ed.), *Cognitive Processing of Chinese and Related Asian Languages* (pp. 77-84). Hong Kong: Chinese University Press.

Chen, H.-C., & Yip, M. (2001). Processing syllabic and sub-syllabic information in Cantonese. *Journal of Psychology in Chinese Societies, 2(2)*, 199-210.

Cleary, M., & Pisoni, D. (2001). Speech perception and spoken word recognition: Research and theory. In E. B. Goldstein (Ed.), *Blackwell Handbook of Perception* (pp. 499-534). Blackwell Publishers Ltd.

Cole, R. A. (1973). Listening for mispronunciations: A measure of what we hear during speech. *Perception & Psychophysics, 11*, 153-156.

Connine, C. M., & Clifton, C., Jr. (1987). Interactive use of lexical information in speech perception. *Journal of Experimental Psychology: Human Perception and Performance, 13*, 291-299.

Connine, C. M., Blasko, D. G., & Titone, D. A. (1993). Do the beginning of words have a special status in auditory word recognition? *Journal of Memory and Language, 32*, 193-210.

Connine, C. M., Blasko, D. G., & Wang, J. (1994). Vertical similarity in spoken word recognition: Multiple lexical activation, individual differences, and the role of sentence context. *Perception and Psychophysics, 56(6)*, 624-636.

Cutler, A. (1997). The comparative perspective on spoken-language processing. *Speech Communication, 21*, 3-15.

Cutler, A., & Chen, H.-C. (1997). Lexical tone in Cantonese spoken-word processing. *Perception and Psychophysics, 59*, 165-179.

Cutler, A., & Otake, T. (2002). Rhymic categories in spoken-word recognition.

Journal of Memory and Language, 46, 296-322.

Cutler, A., Sebastian-Galles, N., Soler-Vilageliu, O., & Van Ooijen., B. (2000). Constraints of vowels and consonants on lexical selection: Cross-linguistic comparisons. *Memory & Cognition, 28(5)*, 746-755.

De Cara, B., Goswami, U. (2002). Similarity relations among spoken words: The special status of rimes in English. *Behavior Research Methods, Instruments, & Computers, 34(3)*, 416-423.

Fok, C. Y. –Y. (1974). *A perceptual study of tones in Cantonese*. Centre of Asian Studies, University of Hong Kong.

Fowler, C. A., Treiman, R., & Gross, J. (1993). The structure of English syllables and polysyllables. *Journal of Memory and Language, 32*, 115-140.

Frauenfelder, U. H. (1996). Computational models of spoken word recognition. In A. Dijkstra & K. de Smedt (Eds.), *Computational psycholinguistics: AI and connectionist models of human language processing*. London: Harvester Press.

Frauenfelder, U. H., & Peeters (1998). Simulating the Time Course of Spoken Word Recognition. In J. Grainger & A. M. Jacobs (Eds.), *Localist Connectionist Approaches to Human Cognition*. New Jersey: Lawrence Erlbaum Associates.

Frauenfelder, U. H., Scholten, M., & Content, A. (2001). Bottom-up inhibition in lexical selection: Phonological mismatch effects in spoken word recognition. *Language and Cognitive Processes, 16 (5/6)*, 583-607.

Gandour, J. (1977). Counterfeit tones in the speech of southern Thai bidialectals. *Lingua, 41*, 125-143.

Gandour, J. (1981). Perceptual dimensions of tone: Evidence from Cantonese. *Journal of Chinese Linguistics, 9*, 20-36.

Gandour, J. (1983). Tone perception in Far Eastern languages. *Journal of Phonetics, 11*, 149-175.

Ganong, W. F. (1980). Phonetic categorization in auditory word perception. *Journal of Experimental Psychology: Human Perception and Performance, 6*, 110-125.

Goldinger, S. D. (1996). Auditory lexical decision. *Language and Cognitive Processes, 11(6)*, 559-567.

Hashimoto, O. -K. Y. (1972). *Studies in Yue dialects 1: Phonology of Cantonese*. Cambridge: Cambridge University Press.

Hombert, J-M, Ohala, J. J. & Ewan, W. G. (1979). Phonetic explanations for the development of tones. *Language, 55(1)*, 37-58.

Howie, J. M. (1976). *Acoustic studies of Mandarin vowels and tones*. Cambridge: Cambridge University Press.

Jusczyk, P. W., & Luce, P. A. (2002). Speech perception. In H. Pashler & S. Yantis (Eds.), *Steven's Handbook of Experimental Psychology Volume 1: Sensation and Perception* (pp. 493-536). NY: John Wiley & Sons, Inc.

Kao, D. (1971). *Structure of the syllable in Cantonese*. The Hague: Mouton.

Kessler, B., & Treiman, R. (1997). Syllable structure and the distribution of phonemes in English syllables. *Journal of Memory and Language, 37*, 295-311.

Lee, G. M. (1993). *Comparative, diachronic and experimental perspectives on the interaction between tone and vowel in standard Cantonese*. Doctoral dissertation. The Ohio State University. University Microfilms International (Order No. 9411999).

Lin, H.-B., & Repp, B. H. (1989). Cues to the perception of Taiwanese tones.

Language and Speech, 32, 25-44.

Lin, Y. T. (1972). *Lin Yutang's Chinese-English Dictionary of Modern Usage*. [On-line]. Available: http://humanum.arts.cuhk.edu.hk/Lexis/Lindict/. Chinese University Press, Humanities Computing Program.

Marslen-Wilson, W. D. & Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. *Cognitive Psychology, 10*, 29-63.

Marslen-Wilson, W. D. (1987). Functional parallelism in spoken word-recognition. *Cognition, 25*, 71-102.

Marslen-Wilson, W. D., & Zwitserlood, P. (1989). Accessing spoken words: The importance of word onsets. *Journal of Experimental Psychology: Human Perception and Performance, 15(3)*, 576-585.

McClelland, J. L. & Elman, J. L. (1986). The TRACE model of speech perception. *Cognitive Psychology, 18*, 1-86.

McLennan, C. T., Luce, P. A., & Luce, J. C. (2003). Representation of lexical form. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29(4)*, 539-553.

McQueen, J. M., Norris, D., & Cutler, A. (1994). Competition in spoken word recognition: Spotting words in other words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20(3)*, 621-638.

Milberg, W., Blumstein, S., & Dworetzky, B. (1988). Phonological factors in lexical access: Evidence from an auditory lexical decision task. *Bulletin of the Psychonomic Society, 26(4)*, 305-308.

Nooteboom, S. G. (1981). Lexical retrieval from fragments of spoken words: beginnings vs endings. *Journal of Phonetics, 9*, 407-424.

Norris, D. (1994). Shortlist: A connectionist model of continuous speech recognition. *Cognition, 52*, 189-234.

Norris, D., McQueen, J. M., & Cutler, A. (2000). Merging information in speech recognition: Feedback is never necessary. *Behavioral and Brain Sciences, 23*, 299-370.

Packard, J. K. (1986). Tone production deficits in nonfluent aphasic Chinese speech. *Brain and Language, 29*, 212-223.

Salasoo, A., & Pisoni, D. B. (1985). Interaction of knowledge sources in spoken word identification. *Journal of Memory and Language, 24*, 210-231.

Samuel, A. G. (1981). The role of bottom-up confirmation in the phonemic restoration illusion. *Journal of Experimental Psychology: Human Perception and Performance, 7*, 1124-1131.

Shen, J.-X. (1993). Slips of the tongue and the syllable structure of Mandarin Chinese. In Shun-Chiu Yau (Ed.), *Essays on the Chinese language by contemporary Chinese scholars* (pp. 139-161). Paris, France: Centre de Recherdches Linguistiques sur l'Asie Orientale – Ecole des Hautes Etudes en Sciences Sociales.

Shen, X. S., & Lin, M. (1991). A perceptual study of Mandarin tones 2 and 3. *Language and Speech, 34*, 145-156.

Slowiaczek, L. M., Nusbaum, H. C., & Pisoni, D. B. (1987). Phonological priming in auditory word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13(1)*, 64-75.

Taft, M., & Chen, H. -C. (1992). Judging homophony in Chinese: The influence of tones. In H. C. Chen & O. J. -L. Tzeng (Ed.), *Languages Processing in Chinese*. (pp. 151-172). Elsevier Science Publishers.

The Linguistic Society of Hong Kong. (1997). *Yue yu pin yin zi biao*.

Treiman, R. (1986). The division between onsets and rimes in English syllables. *Journal of Memory and Language, 25*, 476-491.

Treiman, R. (1988). Distributional constraints and syllable structure in English. *Journal of Phonetics, 16*, 221-229.

Treiman, R., & Kessler, B. (1995). In defense of an onset-rime syllable structure for English. *Language and speech, 38(2)*, 127-142.

Treiman, R., Kessler, B., & Bick, S. (2003). Influence of consonantal context on the pronunciation of vowels: A comparison of human readers and computational models. *Cognition, 88(1)*, 49-78.

Treiman, R., Fowler, C. A., Gross, J., Berch, D., & Weatherston, S. (1995). Syllable structure or word structure? Evidence for onset and rime units with disyllabic and trisyllabic stimuli. *Journal of Memory and Language, 34*, 132-155.

Tsang, K. K., & Hoosain, R. (1979). Segmental phonemes and tonal phonemes in comprehension of Cantonese. *Psychologia, 22*, 222-224.

Tyler, L. K., & Frauenfelder, U. H. (1987). The process of spoken word recognition: An introduction. In L. K. Tyler and U. H. Frauenfelder (Eds.), *Spoken Word Recognition* (pp. 1-21). Cambridge, MA: MIT Press.

Vance, T. J. (1977). Tonal distinctions in Cantonese. *Phonetica, 34*, 93-107.

Van Ooijen, B. (1996). Vowel mutability and lexical selection in English: Evidence from a word reconstruction task. *Memory & Cognition, 24(5)*, 573-583.

Wang, S. Y. (1967). Phonological features of tone. *International Journal of American Linguistics, 33(2)*, 93-105.

Warren, P., & Marslen-Wilson, W. D. (1987). Continuous uptake of acoustic cues in spoken word recognition. *Perception & Psychophysics, 41(3),* 262-275.

Ye, -Y., & Connine, C. M. (1999). Processing spoken Chinese: The role of tone information. *Language and Cognitive Processes, 14*, 609-630.

Yip, M. (2001). Phonological priming in Cantonese spoken-word processing. *Psychologia, 44*, 223-229.

Yip, M. (2002). *Tone*. Cambridge: Cambridge University Press.

Zwitserlood, P. (1989). The locus of the effects of sentential-semantic context in spoken-word processing. *Cognition, 32*, 25-64.

Appendix I: Test Items used in Experiment 1

Condition 1

Item No.	Prime		Translation	Target		Translation
1 (x)	冰	*bing1*	(ice)	塊	*faai3*	(piece)
2	波	*bo1*	(ball *)	浪	*long6*	(wave)
3	杯	*bui1*	(cup)	蓋	*goi3*	(lid)
4	車	*ce1*	(vehicle)	輪	*leon4*	(wheel)
5	泉	*cyun4*	(spring)	水	*seoi2*	(water)
6	家	*gaa1*	(home)	庭	*ting4*	(home)
7	膠	*gaau1*	(rubber)	袋	*doi2*	(bag)
8	金	*gam1*	(gold)	鏈	*lin2*	(chain)
9	腳	*goek3*	(foot)	板	*baan2*	(a flat piece)
10 (x)	球	*kau4*	(ball)	類	*leoi6*	(class)
11 (x)	樓	*lau4*	(storied building)	宇	*jyu5*	(building)
12	面	*min6*	(face)	孔	*hung2*	(hole)
13	眼	*ngaan5*	(eye)	鏡	*geng2*	(mirror)
14	鵝	*ngo4*	(goose)	腸	*coeng2*	(intestine)
15	山	*saan1*	(mountain)	頂	*deng2*	(top)
16	石	*sek6*	(stone)	塊	*faai3*	(piece)
17 (x)	線	*sin3*	(thread)	條	*tiu4*	(long piece)
18	書	*syu1*	(book)	桌	*coek3*	(desk)
19	雪	*syut3*	(snow)	花	*faa1*	(flower)
20	姐	*ze2*	(elder sister)	夫	*fu1*	(husband)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix I: Test Items used in Experiment 1 (cont'd)

Condition 1

Item no.	Prime		Translation	Target		Translation
21 (x)	星	*sing1*	(star)	際	*zai3*	(border)
22	歌	*go1*	(song)	舞	*mou5*	(dance)
23	灰	*fui1*	(ashes)	塵	*can4*	(dust)
24	遮	*ze1*	(umbrella *)	柄	*beng3*	(handle)
25	權	*kyun4*	(power)	利	*lei6*	(profit)
26	瓜	*gwaa1*	(melon)	子	*zi2*	(seeds of plants)
27	貓	*maau1*	(cat)	仔	*zai2*	(kid)
28	心	*sam1*	(heart)	靈	*ling4*	(spirit)
29	雀	*zoek3*	(sparrow)	巢	*caau4*	(nest *)
30 (x)	喉	*hau4*	(pipe *)	管	*gun2*	(pipe)
31 (x)	仇	*sau4*	(enemy)	恨	*han6*	(hatred)
32	電	*din6*	(electricity)	腦	*nou5*	(brain)
33	晚	*maan5*	(evening)	霞	*haa4*	(rosy cloud)
34	婆	*po4*	(woman)	媳	*sik1*	(daughter-in-law)
35	餐	*caan1*	(meal)	具	*geoi6*	(tool)
36	劇	*kek6*	(theater)	本	*bun2*	(manuscript copy)
37 (x)	戰	*zin3*	(war)	亂	*lyun6*	(state of chaos)
38	豬	*zyu1*	(pig)	扒	*paa2*	(steak *)
39	血	*hyut3*	(blood)	液	*jik6*	(fluid)
40	茄	*ke2*	(tomato)	瓜	*gwaa1*	(melon)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix I: Test Items used in Experiment 1 (cont'd)

Condition 2

Item no.	Prime		Translation	Target		Translation
1 (x)	星	*sing1*	(star)	塊	*faai3*	(piece)
2	歌	*go1*	(song)	浪	*long6*	(wave)
3	灰	*fui1*	(ashes)	蓋	*goi3*	(lid)
4	遮	*ze1*	(umbrella *)	輪	*leon4*	(wheel)
5	權	*kyun4*	(power)	水	*seoi2*	(water)
6	瓜	*gwaa1*	(melon)	庭	*ting4*	(home)
7	貓	*maau1*	(cat)	袋	*doi2*	(bag)
8	心	*sam1*	(heart)	鏈	*lin2*	(chain)
9	雀	*zoek3*	(sparrow)	板	*baan2*	(a flat piece)
10 (x)	喉	*hau4*	(pipe *)	類	*leoi6*	(class)
11 (x)	仇	*sau4*	(enemy)	宇	*jyu5*	(building)
12	電	*din6*	(electricity)	孔	*hung2*	(hole)
13	晚	*maan5*	(evening)	鏡	*geng2*	(mirror)
14	婆	*po4*	(woman)	腸	*coeng2*	(intestine)
15	餐	*caan1*	(meal)	頂	*deng2*	(top)
16	劇	*kek6*	(theater)	塊	*faai3*	(piece)
17 (x)	戰	*zin3*	(war)	條	*tiu4*	(long piece)
18	豬	*zyu1*	(pig)	桌	*coek3*	(desk)
19	血	*hyut3*	(blood)	花	*faa1*	(flower)
20	茄	*ke2*	(tomato)	夫	*fu1*	(husband)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix I: Test Items used in Experiment 1 (cont'd)

Condition 2

Item No.	Prime		Translation	Target		Translation
21 (x)	冰	*bing1*	(ice)	際	*zai3*	(border)
22	波	*bo1*	(ball *)	舞	*mou5*	(dance)
23	杯	*bui1*	(cup)	塵	*can4*	(dust)
24	車	*ce1*	(vehicle)	柄	*beng3*	(handle)
25	泉	*cyun4*	(spring)	利	*lei6*	(profit)
26	家	*gaa1*	(home)	子	*zi2*	(seeds of plants)
27	膠	*gaau1*	(rubber)	仔	*zai2*	(kid)
28	金	*gam1*	(gold)	靈	*ling4*	(spirit)
29	腳	*goek3*	(foot)	巢	*caau4*	(nest *)
30 (x)	球	*kau4*	(ball)	管	*gun2*	(pipe)
31 (x)	樓	*lau4*	(storied building)	恨	*han6*	(hatred)
32	面	*min6*	(face)	腦	*nou5*	(brain)
33	眼	*ngaan5*	(eye)	霞	*haa4*	(rosy cloud)
34	鵝	*ngo4*	(goose)	媳	*sik1*	(daughter-in-law)
35	山	*saan1*	(mountain)	具	*geoi6*	(tool)
36	石	*sek6*	(stone)	本	*bun2*	(manuscript copy)
37 (x)	線	*sin3*	(thread)	亂	*lyun6*	(state of chaos)
38	書	*syu1*	(book)	扒	*paa2*	(steak *)
39	雪	*syut3*	(snow)	液	*jik6*	(fluid)
40	姐	*ze2*	(elder sister)	瓜	*gwaa1*	(melon)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix I: Test Items used in Experiment 1 (cont'd)

Condition 3

Item No.	Prime	Target		Translation	Item No.	Prime	Target		Translation
1 (x)	*kwing1*	塊	*faai3*	(piece)	21 (x)	*kwing1*	際	*zai3*	(border)
2	*kwo1*	浪	*long6*	(wave)	22	*kwo1*	舞	*mou5*	(dance)
3	*dui1*	蓋	*goi3*	(lid)	23	*dui1*	塵	*can4*	(dust)
4	*we1*	輪	*leon4*	(wheel)	24	*we1*	柄	*beng3*	(handle)
5	*myun4*	水	*seoi2*	(water)	25	*myun4*	利	*lei6*	(profit)
6	*jaa1*	庭	*ting4*	(home)	26	*jaa1*	子	*zi2*	(seeds of plants)
7	*taau1*	袋	*doi2*	(bag)	27	*taau1*	仔	*zai2*	(kid)
8	*fam1*	鏈	*lin2*	(chain)	28	*fam1*	靈	*ling4*	(spirit)
9	*moek3*	板	*baan2*	(a flat piece)	29	*moek3*	巢	*caau4*	(nest *)
10 (x)	*bau4*	類	*leoi6*	(class)	30 (x)	*bau4*	管	*gun2*	(pipe)
11 (x)	*wau4*	宇	*jyu5*	(building)	31 (x)	*wau4*	恨	*han6*	(hatred)
12	*fin6*	孔	*hung2*	(hole)	32	*fin6*	腦	*nou5*	(brain)
13	*kaan5*	鏡	*geng2*	(mirror)	33	*kaan5*	霞	*haa4*	(rosy cloud
14	*kwo4*	腸	*coeng2*	(intestine)	34	*kwo4*	媳	*sik1*	(daughter-in-law)
15	*jaan1*	頂	*deng2*	(top)	35	*jaan1*	具	*geoi6*	(tool)
16	*mek6*	塊	*faai3*	(piece)	36	*mek6*	本	*bun2*	(manuscrip copy)
17 (x)	*win3*	條	*tiu4*	(long piece)	37 (x)	*win3*	亂	*lyun6*	(state of chaos)
18	*myu1*	桌	*coek3*	(desk)	38	*myu1*	扒	*paa2*	(steak *)
19	*myut3*	花	*faa1*	(flower)	39	*myut3*	液	*jik6*	(fluid)
20	*te2*	夫	*fu1*	(husband)	40	*te2*	瓜	*gwaa1*	(melon)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix I: Test Items used in Experiment 1 (cont'd)

Condition 4

Item No.	Prime		Translation	Target		Translation
1 (x)	頭	*tau4*	(head)	塊	*faai3*	(piece)
2	手	*sau2*	(hand)	浪	*long6*	(wave)
3	口	*hau2*	(mouth)	蓋	*goi3*	(lid)
4	枱	*toi2*	(table)	輪	*leon4*	(wheel)
5	艇	*teng5*	(boat)	水	*seoi2*	(water)
6	菜	*coi3*	(vegetables)	庭	*ting4*	(home)
7	友	*jau5*	(friend)	袋	*doi2*	(bag)
8	店	*dim3*	(shop)	鏈	*lin2*	(chain)
9	煙	*jin1*	(smoke)	板	*baan2*	(a flat piece)
10 (x)	標	*biu1*	(target)	類	*leoi6*	(class)
11 (x)	掌	*zoeng2*	(palm)	宇	*jyu5*	(building)
12	湯	*tong1*	(soup)	孔	*hung2*	(hole)
13	蕉	*ziu1*	(banana)	鏡	*geng2*	(mirror)
14	奶	*naai3*	(milk)	腸	*coeng2*	(intestine)
15	牛	*ngau4*	(cow)	頂	*deng2*	(top)
16	槍	*coeng1*	(pistol)	塊	*faai3*	(piece)
17 (x)	鬼	*gwai2*	(ghost)	條	*tiu4*	(long piece)
18	糖	*tong4*	(sugar)	桌	*coek3*	(desk)
19	簿	*bou2*	(notebook)	花	*faa1*	(flower)
20	薯	*syu4*	(potato)	夫	*fu1*	(husband)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix I: Test Items used in Experiment 1 (cont'd)

Condition 4

Item No.	Prime		Translation	Target		Translation
21 (x)	頭	*tau4*	(head)	際	*zai3*	(border)
22	手	*sau2*	(hand)	舞	*mou5*	(dance)
23	口	*hau2*	(mouth)	塵	*can4*	(dust)
24	枱	*toi2*	(table)	柄	*beng3*	(handle)
25	艇	*teng5*	(boat)	利	*lei6*	(profit)
26	菜	*coi3*	(vegetables)	子	*zi2*	(seeds of plants)
27	友	*jau5*	(friend)	仔	*zai2*	(kid)
28	店	*dim3*	(shop)	靈	*ling4*	(spirit)
29	煙	*jin1*	(smoke)	巢	*caau4*	(nest *)
30 (x)	標	*biu1*	(target)	管	*gun2*	(pipe)
31 (x)	掌	*zoeng2*	(palm)	恨	*han6*	(hatred)
32	湯	*tong1*	(soup)	腦	*nou5*	(brain)
33	蕉	*ziu1*	(banana)	霞	*haa4*	(rosy cloud)
34	奶	*naai3*	(milk)	媳	*sik1*	(daughter-in-law)
35	牛	*ngau4*	(cow)	具	*geoi6*	(tool)
36	槍	*coeng1*	(pistol)	本	*bun2*	(manuscript copy)
37 (x)	鬼	*gwai2*	(ghost)	亂	*lyun6*	(state of chaos)
38	糖	*tong4*	(sugar)	扒	*paa2*	(steak *)
39	簿	*bou2*	(notebook)	液	*jik6*	(fluid)
40	薯	*syu4*	(potato)	瓜	*gwaa1*	(melon)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix I: Test Items used in Experiment 1 (cont'd)

Condition 5

Item No.	Prime	Target		Translation	Item No.	Prime	Target		Translation
1 (x)	*te2*	塊	*faai3*	(piece)	21 (x)	*te2*	際	*zai3*	(border)
2	*win3*	浪	*long6*	(wave)	22	*win3*	舞	*mou5*	(dance)
3	*fin6*	蓋	*goi3*	(lid)	23	*fin6*	塵	*can4*	(dust)
4	*mek6*	輪	*leon4*	(wheel)	24	*mek6*	柄	*beng3*	(handle)
5	*jaan1*	水	*seoi2*	(water)	25	*jaan1*	利	*lei6*	(profit)
6	*myut3*	庭	*ting4*	(home)	26	*myut3*	子	*zi2*	(seeds of plants)
7	*kaan5*	袋	*doi2*	(bag)	27	*kaan5*	仔	*zai2*	(kid)
8	*moek3*	鏈	*lin2*	(chain)	28	*moek3*	靈	*ling4*	(spirit)
9	*fam1*	板	*baan2*	(a flat piece)	29	*fam1*	巢	*caau4*	(nest *)
10 (x)	*myu1*	類	*leoi6*	(class)	30 (x)	*myu1*	管	*gun2*	(pipe)
11 (x)	*kwing1*	宇	*jyu5*	(building)	31 (x)	*kwing1*	恨	*han6*	(hatred)
12	*kwo1*	孔	*hung2*	(hole)	32	*kwo1*	腦	*nou5*	(brain)
13	*dui1*	鏡	*geng2*	(mirror)	33	*dui1*	霞	*haa4*	(rosy cloud
14	*we3*	腸	*coeng2*	(intestine)	34	*we3*	媳	*sik1*	(daughter-in-law)
15	*myun4*	頂	*deng2*	(top)	35	*myun4*	具	*geoi6*	(tool)
16	*jaa1*	塊	*faai3*	(piece)	36	*jaa1*	本	*bun2*	(manuscrip copy)
17 (x)	*kwo2*	條	*tiu4*	(long piece)	37 (x)	*kwo2*	亂	*lyun6*	(state of chaos)
18	*taau5*	桌	*coek3*	(desk)	38	*taau5*	扒	*paa2*	(steak *)
19	*wau4*	花	*faa1*	(flower)	39	*wau4*	液	*jik6*	(fluid)
20	*bau4*	夫	*fu1*	(husband)	40	*bau4*	瓜	*gwaa1*	(melon)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix II: Test Items used in Experiment 2

Condition 1

Item No.	Prime		Translation	Target		Translation
1	包	*baau1*	(bag)	裹	*gwo2*	(parcel)
2 (x)	筆	*bat1*	(pencil)	筒	*tung2*	(tube-shaped container)
3	杯	*bui1*	(cup)	蓋	*goi3*	(lid)
4	橙	*caang2*	(orange)	色	*sik1*	(color)
5	塵	*can4*	(dust)	土	*tou2*	(soil)
6	詞	*ci4*	(words)	語	*jyu5*	(word)
7	廚	*cyu4*	(kitchen)	師	*si1*	(professional people)
8	地	*dei6*	(ground)	方	*fong1*	(plane)
9	刀	*dou1*	(knife)	柄	*beng3*	(handle)
10	火	*fo2*	(fire)	車	*ce1*	(vehicle)
11 (x)	風	*fung1*	(wind)	向	*hoeng3*	(direction)
12	計	*gai3*	(plan)	劃	*waak6*	(to divide)
13	根	*gan1*	(roots)	本	*bun2*	(root of plants)
14	機	*gei1*	(short for mechanical contrivances)	械	*haai6*	(instruments)
15	鏡	*geng3*	(mirror)	子	*zi2*	(offspring)
16 (x)	警	*ging2*	(police)	署	*cyu5*	(official bureau)
17	江	*gong1*	(river)	水	*seoi2*	(water)
18	工	*gung1*	(manual labor)	作	*zok3*	(profession)
19 (x)	音	*jam1*	(sound)	樂	*ngok6*	(music)
20	日	*jat6*	(daytime)	光	*gwong1*	(light)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix II: Test Items used in Experiment 2 (cont'd)

Condition 1

Item No.	Prime		Translation	Target		Translation
21	錶	*biu1*	(watch)	帶	*daai3*	(belt)
22 (x)	邊	*bin1*	(border)	緣	*jyun4*	(border)
23	班	*baan1*	(class in school)	長	*zoeng2*	(chief)
24	草	*cou2*	(grass)	葯	*joek6*	(medicine)
25	錢	*cin4*	(money)	幣	*bai6*	(coins)
26	材	*coi4*	(material)	料	*liu2*	(material)
27	茶	*caa4*	(tea)	葉	*jip6*	(leaf)
28	毒	*duk6*	(poison)	品	*ban2*	(product)
29	燈	*dang1*	(light)	火	*fo2*	(fire)
30	苦	*fu2*	(bitter)	茶	*caa4*	(tea)
31 (x)	夫	*fu1*	(husband)	人	*jan4*	(man)
32	記	*gei3*	(essays)	錄	*luk6*	(record)
33	骨	*gwat1*	(bone)	頭	*tau4*	(head)
34	光	*gwong1*	(light)	芒	*mong4*	(spike)
35	價	*gaa3*	(price)	錢	*cin4*	(money)
36 (x)	鬼	*gwai2*	(ghost)	魂	*wan4*	(soul)
37	歌	*go1*	(song)	手	*sau2*	(hand)
38	軍	*gwan1*	(armed forces)	隊	*deoi2*	(group)
39 (x)	衣	*ji1*	(clothing)	服	*fuk6*	(clothes)
40	藥	*joek6*	(medicine)	材	*coi4*	(material)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix II: Test Items used in Experiment 2 (cont'd)

Condition 2

Item No.	Prime		Translation	Target		Translation
1	錶	*biu1*	(watch)	裹	*gwo2*	(parcel)
2 (x)	邊	*bin1*	(border)	筒	*tung2*	(tube-shaped container)
3	班	*baan1*	(class in school)	蓋	*goi3*	(lid)
4	草	*cou2*	(grass)	色	*sik1*	(color)
5	錢	*cin4*	(money)	土	*tou2*	(soil)
6	材	*coi4*	(material)	語	*jyu5*	(word)
7	茶	*caa4*	(tea)	師	*si1*	(professional people)
8	毒	*duk6*	(poison)	方	*fong1*	(plane)
9	燈	*dang1*	(light)	柄	*beng3*	(handle)
10	苦	*fu2*	(bitter)	車	*ce1*	(vehicle)
11 (x)	夫	*fu1*	(husband)	向	*hoeng3*	(direction)
12	記	*gei3*	(essays)	劃	*waak6*	(to divide)
13	骨	*gwat1*	(bone)	本	*bun2*	(root of plants)
14	光	*gwong1*	(light)	械	*haai6*	(instruments)
15	價	*gaa3*	(price)	子	*zi2*	(offspring)
16 (x)	鬼	*gwai2*	(ghost)	署	*cyu5*	(official bureau)
17	歌	*go1*	(song)	水	*seoi2*	(water)
18	軍	*gwan1*	(armed forces)	作	*zok3*	(profession)
19 (x)	衣	*ji1*	(clothing)	樂	*ngok6*	(music)
20	藥	*joek6*	(medicine)	光	*gwong1*	(light)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix II: Test Items used in Experiment 2 (cont'd)

Condition 2

Item No.	Prime		Translation	Target		Translation
21	包	*baau1*	(bag)	帶	*daai3*	(belt)
22 (x)	筆	*bat1*	(pencil)	緣	*jyun4*	(border)
23	杯	*bui1*	(cup)	長	*zoeng2*	(chief)
24	橙	*caang2*	(orange)	葯	*joek6*	(medicine)
25	塵	*can4*	(dust)	幣	*bai6*	(coins)
26	詞	*ci4*	(words)	料	*liu2*	(material)
27	廚	*cyu4*	(kitchen)	葉	*jip6*	(leaf)
28	地	*dei6*	(ground)	品	*ban2*	(product)
29	刀	*dou1*	(knife)	火	*fo2*	(fire)
30	火	*fo2*	(fire)	茶	*caa4*	(tea)
31 (x)	風	*fung1*	(wind)	人	*jan4*	(man)
32	計	*gai3*	(plan)	錄	*luk6*	(record)
33	根	*gan1*	(roots)	頭	*tau4*	(head)
34	機	*gei1*	(short for mechanical contrivances)	芒	*mong4*	(spike)
35	鏡	*geng3*	(mirror)	錢	*cin4*	(money)
36 (x)	警	*ging2*	(police)	魂	*wan4*	(soul)
37	江	*gong1*	(river)	手	*sau2*	(hand)
38	工	*gung1*	(manual labor)	隊	*deoi2*	(group)
39 (x)	音	*jam1*	(sound)	服	*fuk6*	(clothes)
40	日	*jat6*	(daytime)	材	*coi4*	(material)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix II: Test Items used in Experiment 2 (cont'd)

Condition 3

Item No.	Prime	Target		Translation	Item No.	Prime	Target		Translation
1	*boe1*	裹	*gwo2*	(parcel)	21	*boe1*	帶	*daai3*	(belt)
2 (x)	*beoi1*	筒	*tung2*	(tube-shaped container)	22 (x)	*beoi1*	緣	*jyun4*	(border)
3	*byu1*	蓋	*goi3*	(lid)	23	*byu1*	長	*zoeng2*	(chief)
4	*cun2*	色	*sik1*	(color)	24	*cun2*	葯	*joek6*	(medicine)
5	*cei4*	土	*tou2*	(soil)	25	*cei4*	幣	*bai6*	(coins)
6	*cot4*	語	*jyu5*	(word)	26	*cot4*	料	*liu2*	(material)
7	*cu4*	師	*si1*	(professional people)	27	*cu4*	葉	*jip6*	(leaf)
8	*dyu6*	方	*fong1*	(plane)	28	*dyu6*	品	*ban2*	(product)
9	*dot1*	柄	*beng3*	(handle)	29	*dot1*	火	*fo2*	(fire)
10	*fim2*	車	*ce1*	(vehicle)	30	*fim2*	茶	*caa4*	(tea)
11 (x)	*foe1*	向	*hoeng3*	(direction)	31 (x)	*foe1*	人	*jan4*	(man)
12	*gek3*	劃	*waak6*	(to divide)	32	*gek3*	錄	*luk6*	(record)
13	*geot1*	本	*bun2*	(root of plants)	33	*geot1*	頭	*tau4*	(head)
14	*geon1*	械	*haai6*	(instruments)	34	*geon1*	芒	*mong4*	(spike)
15	*geot3*	子	*zi2*	(offspring)	35	*geot3*	錢	*cin4*	(money)
16 (x)	*gi2*	署	*cyu5*	(official bureau)	36 (x)	*gi2*	魂	*wan4*	(soul)
17	*gyu1*	水	*seoi2*	(water)	37	*gyu1*	手	*sau2*	(hand)
18	*gek1*	作	*zok3*	(profession)	38	*gek1*	隊	*deoi2*	(group)
19 (x)	*ju1*	樂	*ngok6*	(music)	39 (x)	*ju1*	服	*fuk6*	(clothes)
20	*jot6*	光	*gwong1*	(light)	40	*jot6*	材	*coi4*	(material)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix II: Test Items used in Experiment 2 (cont'd)

Condition 4

Item No.	Prime		Translation	Target		Translation
1	利	*lei6*	(profit)	裹	*gwo2*	(parcel)
2 (x)	信	*seon3*	(letter)	筒	*tung2*	(tube-shaped container)
3	命	*ming6*	(life)	蓋	*goi3*	(lid)
4	門	*mun4*	(door)	色	*sik1*	(color)
5	政	*zing3*	(administration)	土	*tou2*	(soil)
6	債	*zaai3*	(debt)	語	*jyu5*	(word)
7	酒	*zau2*	(wine)	師	*si1*	(professional people)
8	數	*sou3*	(number)	方	*fong1*	(plane)
9	面	*min6*	(face)	柄	*beng3*	(handle)
10	路	*lou6*	(road)	車	*ce1*	(vehicle)
11 (x)	木	*muk6*	(wood)	向	*hoeng3*	(direction)
12	山	*saan1*	(mountain)	劃	*waak6*	(to divide)
13	罪	*zoei6*	(sin)	本	*bun2*	(root of plants)
14	影	*jing2*	(movie)	械	*haai6*	(instruments)
15	商	*soeng1*	(commerce)	子	*zi2*	(offspring)
16 (x)	鐘	*zung1*	(clock)	署	*cyu5*	(official bureau)
17	胃	*wai6*	(stomach)	水	*seoi2*	(water)
18	時	*si4*	(time)	作	*zok3*	(profession)
19 (x)	體	*tai2*	(body)	樂	*ngok6*	(music)
20	水	*seoi2*	(water)	光	*gwong1*	(light)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix II: Test Items used in Experiment 2 (cont'd)

Condition 4

Item No.	Prime		Translation	Target		Translation
21	利	*lei6*	(profit)	帶	*daai3*	(belt)
22 (x)	信	*seon3*	(letter)	緣	*jyun4*	(border)
23	命	*ming6*	(life)	長	*zoeng2*	(chief)
24	門	*mun4*	(door)	葯	*joek6*	(medicine)
25	政	*zing3*	(administration)	幣	*bai6*	(coins)
26	債	*zaai3*	(debt)	料	*liu2*	(material)
27	酒	*zau2*	(wine)	葉	*jip6*	(leaf)
28	數	*sou3*	(number)	品	*ban2*	(product)
29	面	*min6*	(face)	火	*fo2*	(fire)
30	路	*lou6*	(road)	茶	*caa4*	(tea)
31 (x)	木	*muk6*	(wood)	人	*jan4*	(man)
32	山	*saan1*	(mountain)	錄	*luk6*	(record)
33	罪	*zoei6*	(sin)	頭	*tau4*	(head)
34	影	*jing2*	(movie)	芒	*mong4*	(spike)
35	商	*soeng1*	(commerce)	錢	*cin4*	(money)
36 (x)	鐘	*zung1*	(clock)	魂	*wan4*	(soul)
37	胃	*wai6*	(stomach)	手	*sau2*	(hand)
38	時	*si4*	(time)	隊	*deoi2*	(group)
39 (x)	體	*tai2*	(body)	服	*fuk6*	(clothes)
40	水	*seoi2*	(water)	材	*coi4*	(material)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix II: Test Items used in Experiment 2 (cont'd)

Condition 5

Item No.	Prime	Target		Translation	Item No.	Prime	Target		Translation
1	*coi6*	裹	*gwo2*	(parcel)	21	*coi6*	帶	*daai3*	(belt)
2 (x)	*fou6*	筒	*tung2*	(tube-shaped container)	22 (x)	*fou6*	緣	*jyun4*	(border)
3	*dou4*	蓋	*goi3*	(lid)	23	*dou4*	長	*zoeng2*	(chief)
4	*fung5*	色	*sik1*	(color)	24	*fung5*	葯	*joek6*	(medicine)
5	*gei5*	土	*tou2*	(soil)	25	*gei5*	幣	*bai6*	(coins)
6	*gun6*	語	*jyu5*	(word)	26	*gun6*	料	*liu2*	(material)
7	*haai2*	師	*si1*	(professional people)	27	*haai2*	葉	*jip6*	(leaf)
8	*gai4*	方	*fong1*	(plane)	28	*gai4*	品	*ban2*	(product)
9	*hei6*	柄	*beng3*	(handle)	29	*hei6*	火	*fo2*	(fire)
10	*hoi3*	車	*ce1*	(vehicle)	30	*hoi3*	茶	*caa4*	(tea)
11 (x)	*ngaa2*	向	*hoeng3*	(direction)	31 (x)	*ngaa2*	人	*jan4*	(man)
12	*joek1*	劃	*waak6*	(to divide)	32	*joek1*	錄	*luk6*	(record)
13	*lou3*	本	*bun2*	(root of plants)	33	*lou3*	頭	*tau4*	(head)
14	*sau5*	械	*haai6*	(instruments)	34	*sau5*	芒	*mong4*	(spike)
15	*sing5*	子	*zi2*	(offspring)	35	*sing5*	錢	*cin4*	(money)
16 (x)	*moi3*	署	*cyu5*	(official bureau)	36 (x)	*moi3*	魂	*wan4*	(soul)
17	*tin6*	水	*seoi2*	(water)	37	*tin6*	手	*sau2*	(hand)
18	*tou6*	作	*zok3*	(profession)	38	*tou6*	隊	*deoi2*	(group)
19 (x)	*tak3*	樂	*ngok6*	(music)	39 (x)	*tak3*	服	*fuk6*	(clothes)
20	*waa3*	光	*gwong1*	(light)	40	*waa3*	材	*coi4*	(material)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix III: Test Items used in Experiment 3

Condition 1

Item No.	Prime		Translation	Target		Translation
1	菜	*coi3*	(vegetable)	心	*sam1*	(heart)
2	刀	*dou1*	(knife)	劍	*gim3*	(sword)
3	科	*fo1*	(class)	舉	*geoi2*	(action)
4 (x)	風	*fung1*	(wind)	暴	*bou6*	(violence)
5	雞	*gai1*	(chickens)	蛋	*daan2*	(egg)
6	機	*gei1*	(short for mechanical contrivances)	械	*haai6*	(instruments)
7	冠	*gun1*	(crown)	冕	*min5*	(ruler's cap)
8	鞋	*haai4*	(shoes)	襪	*mat6*	(socks)
9	喜	*hei2*	(happiness)	樂	*lok6*	(pleasure)
10	海	*hoi2*	(sea)	洋	*joeng4*	(ocean)
11 (x)	約	*joek3*	(treaty)	束	*cuk1*	(tie up)
12	爐	*lou4*	(stove)	火	*fo2*	(fire)
13	蚊	*man1*	(mosquito)	拍	*paak2*	(bat *)
14	牙	*ngaa4*	(tooth)	痛	*tung3*	(pain)
15	手	*sau2*	(hand)	腳	*goek3*	(leg)
16	城	*sing4*	(city)	堡	*bou2*	(fortress)
17	天	*tin1*	(sky)	氣	*hei3*	(air)
18	圖	*tou4*	(picture)	書	*syu1*	(book)
19	畫	*waa2*	(painting)	筆	*bat1*	(brush)
20 (x)	紙	*zi2*	(paper)	碎	*seoi3*	(broken bits)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix III: Test Items used in Experiment 3 (cont'd)

Condition 1

Item no.	Prime		Translation	Target		Translation
21	材	*coi4*	(material)	料	*liu2*	(material)
22	道	*dou6*	(street)	理	*lei5*	(reason)
23	課	*fo3*	(lesson)	文	*man4*	(writing)
24 (x)	俸	*fung2*	(salary)	祿	*luk6*	(salary)
25	計	*gai3*	(plan)	謀	*mau4*	(plan)
26	記	*gei3*	(essays)	者	*ze2*	(person)
27	管	*gun2*	(pipe)	道	*dou6*	(path)
28	蟹	*haai5*	(crab)	肉	*juk6*	(meat)
29	戲	*hei3*	(theater)	言	*jin4*	(speech)
30	害	*hoi6*	(cause of trouble)	處	*cyu3*	(point)
31 (x)	藥	*joek6*	(medicine)	水	*seoi2*	(water)
32	路	*lou6*	(road)	口	*hau2*	(mouth)
33	文	*man4*	(writing)	字	*zi6*	(words)
34	瓦	*ngaa5*	(earthen ware)	礫	*lik1*	(piece)
35	仇	*sau4*	(enemy)	敵	*dik6*	(enemy)
36	性	*sing3*	(sex)	別	*bit6*	(distinction)
37	田	*tin4*	(farm)	野	*je5*	(countryside)
38	兔	*tou3*	(rabbit)	仔	*zai2*	(kid)
39	話	*waa6*	(speech)	語	*jyu5*	(word)
40 (x)	字	*zi6*	(words)	句	*geoi3*	(sentence)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix III: Test Items used in Experiment 3 (cont'd)

Condition 2

Item no.	Prime		Translation	Target		Translation
1	材	*coi4*	(material)	心	*sam1*	(heart)
2	道	*dou6*	(street)	劍	*gim3*	(sword)
3	課	*fo3*	(lesson)	舉	*geoi2*	(action)
4 (x)	俸	*fung2*	(salary)	暴	*bou6*	(violence)
5	計	*gai3*	(plan)	蛋	*daan2*	(egg)
6	記	*gei3*	(essays)	械	*haai6*	(instruments)
7	管	*gun2*	(pipe)	冕	*min5*	(ruler's cap)
8	蟹	*haai5*	(crab)	襪	*mat6*	(socks)
9	戲	*hei3*	(theater)	樂	*lok6*	(pleasure)
10	害	*hoi6*	(cause of trouble)	洋	*joeng4*	(ocean)
11 (x)	藥	*joek6*	(medicine)	束	*cuk1*	(tie up)
12	路	*lou6*	(road)	火	*fo2*	(fire)
13	文	*man4*	(writing)	拍	*paak2*	(bat *)
14	瓦	*ngaa5*	(earthen ware)	痛	*tung3*	(pain)
15	仇	*sau4*	(enemy)	腳	*goek3*	(leg)
16	性	*sing3*	(sex)	堡	*bou2*	(fortress)
17	田	*tin4*	(farm)	氣	*hei3*	(air)
18	兔	*tou3*	(rabbit)	書	*syu1*	(book)
19	話	*waa6*	(speech)	筆	*bat1*	(brush)
20 (x)	字	*zi6*	(words)	碎	*seoi3*	(broken bits)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix III: Test Items used in Experiment 3 (cont'd)

Condition 2

Item No.	Prime		Translation	Target		Translation
21	菜	*coi3*	(vegetable)	料	*liu2*	(material)
22	刀	*dou1*	(knife)	理	*lei5*	(reason)
23	科	*fo1*	(class)	文	*man4*	(writing)
24 (x)	風	*fung1*	(wind)	祿	*luk6*	(salary)
25	雞	*gai1*	(chickens)	謀	*mau4*	(plan)
26	機	*gei1*	(short for mechanical contrivances)	者	*ze2*	(person)
27	冠	*gun1*	(crown)	道	*dou6*	(path)
28	鞋	*haai4*	(shoes)	肉	*juk6*	(meat)
29	喜	*hei2*	(happiness)	言	*jin4*	(speech)
30	海	*hoi2*	(sea)	處	*cyu3*	(point)
31 (x)	約	*joek3*	(treaty)	水	*seoi2*	(water)
32	爐	*lou4*	(stove)	口	*hau2*	(mouth)
33	蚊	*man1*	(mosquito)	字	*zi6*	(words)
34	牙	*ngaa4*	(tooth)	礫	*lik1*	(piece)
35	手	*sau2*	(hand)	敵	*dik6*	(enemy)
36	城	*sing4*	(city)	別	*bit6*	(distinction)
37	天	*tin1*	(sky)	野	*je5*	(countryside)
38	圖	*tou4*	(picture)	仔	*zai2*	(kid)
39	畫	*waa2*	(painting)	語	*jyu5*	(word)
40 (x)	紙	*zi2*	(paper)	句	*geoi3*	(sentence)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix III: Test Items used in Experiment 3 (cont'd)

Condition 3

Item No.	Prime	Target		Translation	Item No.	Prime	Target		Translation
1	*coi6*	心	*sam1*	(heart)	21	*coi6*	料	*liu2*	(material)
2	*dou4*	劍	*gim3*	(sword)	22	*dou4*	理	*lei5*	(reason)
3	*fo6*	舉	*geoi2*	(action)	23	*fo6*	文	*man4*	(writing)
4 (x)	*fung5*	暴	*bou6*	(violence)	24 (x)	*fung5*	祿	*luk6*	(salary)
5	*gai4*	蛋	*daan2*	(egg)	25	*gai4*	謀	*mau4*	(plan)
6	*gei5*	械	*haai6*	(instruments)	26	*gei5*	者	*ze2*	(person)
7	*gun6*	冕	*min5*	(ruler's cap)	27	*gun6*	道	*dou6*	(path)
8	*haai2*	襪	*mat6*	(socks)	28	*haai2*	肉	*juk6*	(meat)
9	*hei6*	樂	*lok6*	(pleasure)	29	*hei6*	言	*jin4*	(speech)
10	*hoi3*	洋	*joeng4*	(ocean)	30	*hoi3*	處	*cyu3*	(point)
11 (x)	*joek1*	束	*cuk1*	(tie up)	31 (x)	*joek1*	水	*seoi2*	(water)
12	*lou3*	火	*fo2*	(fire)	32	*lou3*	口	*hau2*	(mouth)
13	*man3*	拍	*paak2*	(bat *)	33	*man3*	字	*zi6*	(words)
14	*ngaa2*	痛	*tung3*	(pain)	34	*ngaa2*	礫	*lik1*	(piece)
15	*sau5*	腳	*goek3*	(leg)	35	*sau5*	敵	*dik6*	(enemy)
16	*sing5*	堡	*bou2*	(fortress)	36	*sing5*	別	*bit6*	(distinction)
17	*tin6*	氣	*hei3*	(air)	37	*tin6*	野	*je5*	(countryside
18	*tou6*	書	*syu1*	(book)	38	*tou6*	仔	*zai2*	(kid)
19	*waa3*	筆	*bat1*	(brush)	39	*waa3*	語	*jyu5*	(word)
20 (x)	*zi5*	碎	*seoi3*	(broken bits)	40 (x)	*zi5*	句	*geoi3*	(sentence)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix III: Test Items used in Experiment 3 (cont'd)

Condition 4

Item No.	Prime		Translation	Target		Translation
1	飯	*faan6*	(rice)	心	*sam1*	(heart)
2	題	*tai4*	(subject)	劍	*gim3*	(sword)
3	病	*beng6*	(illness)	舉	*geoi2*	(action)
4 (x)	牆	*ceong4*	(wall)	暴	*bou6*	(violence)
5	賊	*caak6*	(thief)	蛋	*daan2*	(egg)
6	名	*ming4*	(name)	械	*haai6*	(instruments)
7	相	*soeng3*	(appearance)	冕	*min5*	(ruler's cap)
8	廠	*cong2*	(factory)	襪	*mat6*	(socks)
9	梯	*tai1*	(ladder)	樂	*lok6*	(pleasure)
10	舞	*mou5*	(dance)	洋	*joeng4*	(ocean)
11 (x)	眉	*mei4*	(eyebrows)	束	*cuk1*	(tie up)
12	鐘	*zung1*	(clock)	火	*fo2*	(fire)
13	理	*lei5*	(reason)	拍	*paak2*	(bat *)
14	齒	*ci2*	(tooth)	痛	*tung3*	(pain)
15	雨	*jyu5*	(rain)	腳	*goek3*	(leg)
16	尾	*mei5*	(tail)	堡	*bou2*	(fortress)
17	實	*sat6*	(fruit)	氣	*hei3*	(air)
18	利	*lei6*	(profit)	書	*syu1*	(book)
19	眉	*mei4*	(eyebrows)	筆	*bat1*	(brush)
20 (x)	魚	*jyu4*	(fish)	碎	*seoi3*	(broken bits)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix III: Test Items used in Experiment 3 (cont'd)

Condition 4

Item No.	Prime		Translation	Target		Translation
21	飯	*faan6*	(rice)	料	*liu2*	(material)
22	題	*tai4*	(subject)	理	*lei5*	(reason)
23	病	*beng6*	(illness)	文	*man4*	(writing)
24 (x)	牆	*ceong4*	(wall)	祿	*luk6*	(salary)
25	賊	*caak6*	(thief)	謀	*mau4*	(plan)
26	名	*ming4*	(name)	者	*ze2*	(person)
27	相	*soeng3*	(appearance)	道	*dou6*	(path)
28	廠	*cong2*	(factory)	肉	*juk6*	(meat)
29	梯	*tai1*	(ladder)	言	*jin4*	(speech)
30	舞	*mou5*	(dance)	處	*cyu3*	(point)
31 (x)	眉	*mei4*	(eyebrows)	水	*seoi2*	(water)
32	鐘	*zung1*	(clock)	口	*hau2*	(mouth)
33	理	*lei5*	(reason)	字	*zi6*	(words)
34	齒	*ci2*	(tooth)	礫	*lik1*	(piece)
35	雨	*jyu5*	(rain)	敵	*dik6*	(enemy)
36	尾	*mei5*	(tail)	別	*bit6*	(distinction)
37	實	*sat6*	(fruit)	野	*je5*	(countryside)
38	利	*lei6*	(profit)	仔	*zai2*	(kid)
39	眉	*mei4*	(eyebrows)	語	*jyu5*	(word)
40 (x)	魚	*jyu4*	(fish)	句	*geoi3*	(sentence)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix III: Test Items used in Experiment 3 (cont'd)

Condition 5

Item No.	Prime	Target		Translation	Item No.	Prime	Target		Translation
1	*bu6*	心	*sam1*	(heart)	21	*bu6*	料	*liu2*	(material)
2	*pi2*	劍	*gim3*	(sword)	22	*pi2*	理	*lei5*	(reason)
3	*boeng6*	舉	*geoi2*	(action)	23	*boeng6*	文	*man4*	(writing)
4 (x)	*keng3*	暴	*bou6*	(violence)	24 (x)	*keng3*	祿	*luk6*	(salary)
5	*jaap5*	蛋	*daan2*	(egg)	25	*jaap5*	謀	*mau4*	(plan)
6	*jong5*	械	*haai6*	(instruments)	26	*jong5*	者	*ze2*	(person)
7	*sut3*	冕	*min5*	(ruler's cap)	27	*sut3*	道	*dou6*	(path)
8	*keon2*	襪	*mat6*	(socks)	28	*keon2*	肉	*juk6*	(meat)
9	*pip1*	樂	*lok6*	(pleasure)	29	*pip1*	言	*jin4*	(speech)
10	*peon1*	洋	*joeng4*	(ocean)	30	*peon1*	處	*cyu3*	(point)
11 (x)	*geot5*	束	*cuk1*	(tie up)	31 (x)	*geot5*	水	*seoi2*	(water)
12	*mot3*	火	*fo2*	(fire)	32	*mot3*	口	*hau2*	(mouth)
13	*boek3*	拍	*paak2*	(bat *)	33	*boek3*	字	*zi6*	(words)
14	*jong6*	痛	*tung3*	(pain)	34	*jong6*	礫	*lik1*	(piece)
15	*bu1*	腳	*goek3*	(leg)	35	*bu1*	敵	*dik6*	(enemy)
16	*tak1*	堡	*bou2*	(fortress)	36	*tak1*	別	*bit6*	(distinction)
17	*meot6*	氣	*hei3*	(air)	37	*meot6*	野	*je5*	(countryside
18	*moi5*	書	*syu1*	(book)	38	*moi5*	仔	*zai2*	(kid)
19	*cu3*	筆	*bat1*	(brush)	39	*cu3*	語	*jyu5*	(word)
20 (x)	*waap1*	碎	*seoi3*	(broken bits)	40 (x)	*waap1*	句	*geoi3*	(sentence)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

(3) "x": Items excluded from analysis.

Appendix IV: Test Items used in Experiment 4

Condition 1

Item No.	Prime		Translation	Target		Translation
1	包	*baau1*	(bag)	裹	*gwo2*	(parcel)
2	冰	*bing1*	(ice)	塊	*faai3*	(piece)
3	波	*bo1*	(wave)	浪	*long6*	(wave)
4	杯	*bui1*	(cup)	蓋	*goi3*	(lid)
5	橙	*caang2* *	(orange)	色	*sik1*	(color)
6	車	*ce1*	(vehicle)	輪	*leon4*	(wheel)
7	詞	*ci4*	(words)	語	*jyu5*	(word)
8	菜	*coi3*	(vegetable)	心	*sam1*	(heart)
9	泉	*cyun4*	(spring)	水	*seoi2*	(water)
10	地	*dei6*	(ground)	方	*fong1*	(plane)
11	刀	*dou1*	(knife)	柄	*beng3*	(handle)
12	火	*fo2*	(fire)	車	*ce1*	(vehicle)
13	風	*fung1*	(wind)	向	*hoeng3*	(direction)
14	家	*gaa1*	(home)	庭	*ting4*	(home)
15	鏡	*geng3*	(mirror)	子	*zi2*	(offspring)
16	腳	*goek3*	(foot)	板	*baan2*	(a flat piece)
17	江	*gong1*	(river)	水	*seoi2*	(water)
18	鞋	*haai4*	(shoes)	襪	*mat6*	(socks)
19	喜	*hei2*	(happiness)	樂	*lok6*	(pleasure)
20	海	*hoi2*	(sea)	洋	*joeng4*	(ocean)

Note:

(1) All syllable markings (except those with a asterisk) are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

Appendix IV: Test Items used in Experiment 4 (cont'd)

Condition 1

Item no.	Prime		Translation	Target		Translation
21	音	*jam1*	(sound)	樂	*ngok6*	(music)
22	日	*jat6*	(daytime)	光	*gwong1*	(light)
23	約	*joek3*	(treaty)	束	*cuk1*	(tie up)
24	球	*kau4*	(ball)	類	*leoi6*	(class)
25	樓	*lau4*	(stored building)	宇	*jyu5*	(building)
26	爐	*lou4*	(stove)	火	*fo2*	(fire)
27	蚊	*man1*	(mosquito)	拍	*paak2*	(bat *)
28	面	*min6*	(face)	孔	*hung2*	(hole)
29	眼	*ngaan5*	(eye)	鏡	*geng2*	(mirror)
30	鵝	*ngo4*	(goose)	腸	*coeng2*	(intestines)
31	山	*saan1*	(mountain)	頂	*deng2*	(top)
32	手	*sau2*	(hand)	腳	*goek3*	(foot)
33	石	*sek6*	(stone)	塊	*faai3*	(piece)
34	線	*sin3*	(thread)	條	*tiu4*	(long piece)
35	書	*syu1*	(book)	桌	*coek3*	(desk)
36	天	*tin1*	(sky)	氣	*hei3*	(air)
37	圖	*tou4*	(picture)	書	*syu1*	(book)
38	畫	*waa2*	(paining)	筆	*bat1*	(brush)
39	姐	*ze2*	(elder sister)	夫	*fu1*	(husband)
40	紙	*zi2*	(paper)	碎	*seoi3*	(broken bits)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

Appendix IV: Test Items used in Experiment 4 (cont'd)

Condition 2

Item No.	Prime	Target		Translation	Item No.	Prime	Target		Translation
1	*boe3*	裹	*gwo2*	(parcel)	21	*ju3*	樂	*ngok6*	(music)
2	*bu2*	塊	*faai3*	(piece)	22	*jot3*	光	*gwong1*	(light)
3	*bau2*	浪	*long6*	(wave)	23	*jong5*	束	*cuk1*	(tie up)
4	*boek6*	蓋	*goi3*	(lid)	24	*kon3*	類	*leoi6*	(class)
5	*cun3*	色	*sik1*	(color)	25	*lot1*	宇	*jyu5*	(building)
6	*coi6*	輪	*leon4*	(wheel)	26	*lon3*	火	*fo2*	(fire)
7	*cot6*	語	*jyu5*	(word)	27	*mim3*	拍	*paak2*	(bat *)
8	*cu2*	心	*sam1*	(heart)	28	*mon1*	孔	*hung2*	(hole)
9	*cei1*	水	*seoi2*	(water)	29	*ngoeng1*	鏡	*geng2*	(mirror)
10	*dyu2*	方	*fong1*	(plane)	30	*nguk5*	腸	*coeng2*	(intestines)
11	*dot6*	柄	*beng3*	(handle)	31	*sut6*	頂	*deng2*	(top)
12	*fim3*	車	*ce1*	(vehicle)	32	*soe1*	腳	*goek3*	(foot)
13	*foe2*	向	*hoeng3*	(direction)	33	*son4*	塊	*faai3*	(piece)
14	*gek3*	庭	*ting4*	(home)	34	*su1*	條	*tiu4*	(long piece)
15	*geot4*	子	*zi2*	(offspring)	35	*sot2*	桌	*coek3*	(desk)
16	*gi1*	板	*baan2*	(a flat piece)	36	*teot2*	氣	*hei3*	(air)
17	*gyu3*	水	*seoi2*	(water)	37	*tot2*	書	*syu1*	(book)
18	*heon3*	襪	*mat6*	(socks)	38	*weot6*	筆	*bat1*	(brush)
19	*hut5*	樂	*lok6*	(pleasure)	39	*zut4*	夫	*fu1*	(husband)
20	*hoek1*	洋	*joeng4*	(ocean)	40	*zon1*	碎	*seoi3*	(broken bits)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

Appendix IV: Test Items used in Experiment 4 (cont'd)

Condition 3

Item No.	Prime	Target		Translation	Item No.	Prime	Target		Translation
1	*taau3*	裹	*gwo2*	(parcel)	21	*pam2*	樂	*ngok6*	(music)
2	*kwing2*	塊	*faai3*	(piece)	22	*tat3*	光	*gwong1*	(light)
3	*kwo2*	浪	*long6*	(wave)	23	*foek2*	束	*cuk1*	(tie up)
4	*hui6*	蓋	*goi3*	(lid)	24	*gwau1*	類	*leoi6*	(class)
5	*faang3*	色	*sik1*	(color)	25	*wau3*	宇	*jyu5*	(building)
6	*we3*	輪	*leon4*	(wheel)	26	*kou1*	火	*fo2*	(fire)
7	*fi6*	語	*jyu5*	(word)	27	*lan6*	拍	*paak2*	(bat *)
8	*moi6*	心	*sam1*	(heart)	28	*gwin3*	孔	*hung2*	(hole)
9	*myun1*	水	*seoi2*	(water)	29	*kaan1*	鏡	*geng2*	(mirror)
10	*zei2*	方	*fong1*	(plane)	30	*kwo5*	腸	*coeng2*	(intestines)
11	*fou6*	柄	*beng3*	(handle)	31	*kaan3*	頂	*deng2*	(top)
12	*kwo4*	車	*ce1*	(vehicle)	32	*bau1*	腳	*goek3*	(foot)
13	*wung6*	向	*hoeng3*	(direction)	33	*nek1*	塊	*faai3*	(piece)
14	*daa6*	庭	*ting4*	(home)	34	*win2*	條	*tiu4*	(long piece)
15	*feng6*	子	*zi2*	(offspring)	35	*byu2*	桌	*coek3*	(desk)
16	*poek1*	板	*baan2*	(a flat piece)	36	*ngin2*	氣	*hei3*	(air)
17	*jong3*	水	*seoi2*	(water)	37	*wou2*	書	*syu1*	(book)
18	*daai1*	襪	*mat6*	(socks)	38	*paa6*	筆	*bat1*	(brush)
19	*tei1*	樂	*lok6*	(pleasure)	39	*he3*	夫	*fu1*	(husband)
20	*boi3*	洋	*joeng4*	(ocean)	40	*wi1*	碎	*seoi3*	(broken bits)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

Appendix IV: Test Items used in Experiment 4 (cont'd)

Condition 4

Item No.	Prime	Target		Translation	Item No.	Prime	Target		Translation
1	*kwing1*	裹	*gwo2*	(parcel)	21	*tak1*	樂	*ngok6*	(music)
2	*we1*	塊	*faai3*	(piece)	22	*fin6*	光	*gwong1*	(light)
3	*mip1*	浪	*long6*	(wave)	23	*man3*	束	*cuk1*	(tie up)
4	*jaa1*	蓋	*goi3*	(lid)	24	*dui4*	類	*leoi6*	(class)
5	*te2*	色	*sik1*	(color)	25	*dut4*	宇	*jyu5*	(building)
6	*joek1*	輪	*leon4*	(wheel)	26	*pi4*	火	*fo2*	(fire)
7	*bau4*	語	*jyu5*	(word)	27	*kwo1*	拍	*paak2*	(bat *)
8	*moek3*	心	*sam1*	(heart)	28	*zei6*	孔	*hung2*	(hole)
9	*wau4*	水	*seoi2*	(water)	29	*zi5*	鏡	*geng2*	(mirror)
10	*kwo6*	方	*fong1*	(plane)	30	*bap4*	腸	*coeng2*	(intestines)
11	*jaan1*	柄	*beng3*	(handle)	31	*keot1*	頂	*deng2*	(top)
12	*haai2*	車	*ce1*	(vehicle)	32	*wek2*	腳	*goek3*	(foot)
13	*moek1*	向	*hoeng3*	(direction)	33	*tin6*	塊	*faai3*	(piece)
14	*peon1*	庭	*ting4*	(home)	34	*fit3*	條	*tiu4*	(long piece)
15	*hoi3*	子	*zi2*	(offspring)	35	*lang1*	桌	*coek3*	(desk)
16	*lou3*	板	*baan2*	(a flat piece)	36	*mot1*	氣	*hei3*	(air)
17	*myu1*	水	*seoi2*	(water)	37	*wim4*	書	*syu1*	(book)
18	*fyun4*	襪	*mat6*	(socks)	38	*peon2*	筆	*bat1*	(brush)
19	*pon2*	樂	*lok6*	(pleasure)	39	*tat2*	夫	*fu1*	(husband)
20	*kwi2*	洋	*joeng4*	(ocean)	40	*neng2*	碎	*seoi3*	(broken bits)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

Appendix IV: Test Items used in Experiment 4 (cont'd)

Condition 5

Item No.	Prime		Translation	Target		Translation
1	利	*lei6*	(profit)	裹	*gwo2*	(parcel)
2	頭	*tau4*	(head)	塊	*faai3*	(piece)
3	手	*sau2*	(hand)	浪	*long6*	(wave)
4	口	*hau2*	(mouth)	蓋	*goi3*	(lid)
5	門	*mun4*	(door)	色	*sik1*	(color)
6	枱	*toi2*	(table *)	輪	*leon4*	(wheel)
7	債	*zaai3*	(debt)	語	*jyu5*	(word)
8	飯	*faan6*	(rice)	心	*sam1*	(heart)
9	艇	*teng5*	(boat)	水	*seoi2*	(water)
10	數	*sou3*	(number)	方	*fong1*	(plane)
11	面	*min6*	(face)	柄	*beng3*	(handle)
12	路	*lou6*	(road)	車	*ce1*	(vehicle)
13	木	*muk6*	(wood)	向	*hoeng3*	(direction)
14	菜	*coi3*	(vegetable)	庭	*ting4*	(home)
15	商	*soeng1*	(commerce)	子	*zi2*	(offspring)
16	煙	*jin1*	(smoke)	板	*baan2*	(a flat piece)
17	胃	*wai6*	(stomach)	水	*seoi2*	(water)
18	廠	*cong2*	(factory)	襪	*mat6*	(socks)
19	梯	*tai1*	(ladder)	樂	*lok6*	(pleasure)
20	舞	*mou5*	(dance)	洋	*joeng4*	(ocean)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

Appendix IV: Test Items used in Experiment 4 (cont'd)

Condition 5

Item no.	Prime		Translation	Target		Translation
21	體	*tai2*	(body)	樂	*ngok6*	(music)
22	水	*seoi2*	(water)	光	*gwong1*	(light)
23	眉	*mei4*	(eyebrows)	束	*cuk1*	(tie up)
24	標	*biu1*	(target)	類	*leoi6*	(class)
25	掌	*zoeng2*	(palm)	宇	*jyu5*	(building)
26	鐘	*zung1*	(clock)	火	*fo2*	(fire)
27	理	*lei5*	(reason)	拍	*paak2*	(bat *)
28	湯	*tong1*	(soup)	孔	*hung2*	(hole)
29	蕉	*ziu1*	(banana)	鏡	*geng2*	(mirror)
30	奶	*naai3*	(milk)	腸	*coeng2*	(intestines)
31	牛	*ngau4*	(cow)	頂	*deng2*	(top)
32	雨	*jyu5*	(rain)	腳	*goek3*	(foot)
33	槍	*coeng1*	(pistol)	塊	*faai3*	(piece)
34	鬼	*gwai2*	(ghost)	條	*tiu4*	(long piece)
35	糖	*tong4*	(sugar)	桌	*coek3*	(desk)
36	實	*sat6*	(fruit)	氣	*hei3*	(air)
37	利	*lei6*	(profit)	書	*syu1*	(book)
38	眉	*mei4*	(eyebrows)	筆	*bat1*	(brush)
39	薯	*syu4*	(potato)	夫	*fu1*	(husband)
40	魚	*jyu4*	(fish)	碎	*seoi3*	(broken bits)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

Appendix IV: Test Items used in Experiment 4 (cont'd)

Condition 6

Item No.	Prime	Target		Translation	Item No.	Prime	Target		Translation
1	*coi6*	裹	*gwo2*	(parcel)	21	*tak3*	樂	*ngok6*	(music)
2	*te2*	塊	*faai3*	(piece)	22	*waa3*	光	*gwong1*	(light)
3	*win3*	浪	*long6*	(wave)	23	*geot5*	束	*cuk1*	(tie up)
4	*fin6*	蓋	*goi3*	(lid)	24	*myu1*	類	*leoi6*	(class)
5	*fung5*	色	*sik1*	(color)	25	*kwing1*	宇	*jyu5*	(building)
6	*mek6*	輪	*leon4*	(wheel)	26	*mot3*	火	*fo2*	(fire)
7	*gun6*	語	*jyu5*	(word)	27	*boek3*	拍	*paak2*	(bat *)
8	*bu6*	心	*sam1*	(heart)	28	*kwo1*	孔	*hung2*	(hole)
9	*jaan1*	水	*seoi2*	(water)	29	*dui1*	鏡	*geng2*	(mirror)
10	*gai4*	方	*fong1*	(plane)	30	*we3*	腸	*coeng2*	(intestines)
11	*hei6*	柄	*beng3*	(handle)	31	*myun4*	頂	*deng2*	(top)
12	*hoi3*	車	*ce1*	(vehicle)	32	*bu1*	腳	*goek3*	(foot)
13	*ngaa2*	向	*hoeng3*	(direction)	33	*jaa1*	塊	*faai3*	(piece)
14	*myut3*	庭	*ting4*	(home)	34	*kwo2*	條	*tiu4*	(long piece)
15	*sing5*	子	*zi2*	(offspring)	35	*taau5*	桌	*coek3*	(desk)
16	*fam1*	板	*baan2*	(a flat piece)	36	*meot6*	氣	*hei3*	(air)
17	*tin6*	水	*seoi2*	(water)	37	*moi5*	書	*syu1*	(book)
18	*keon2*	襪	*mat6*	(socks)	38	*cu3*	筆	*bat1*	(brush)
19	*pip1*	樂	*lok6*	(pleasure)	39	*bau4*	夫	*fu1*	(husband)
20	*peon1*	洋	*joeng4*	(ocean)	40	*waap1*	碎	*seoi3*	(broken bits)

Note:

(1) All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).

(2) All translations (except those with an asterisk) are in accordance with *Lin Yutang's Chinese-English Dictionary of Modern Usage* (Lin, T. Y., Chinese University Press, Humanities Computing Program, 1972).

Appendix V: Stimulus Allocation in Experiments 1, 2, and 3, and Stimulus in Each Block

Stimulus Allocation in Experiments 1, 2, and 3

Item no.	Condition 1 (Original word)	Condition 2 (Onset-altered word/ Rime-altered word/ Tone-altered word)	Condition 3 (Onset-altered nonword/ Rime-altered nonword/ Tone-altered nonword)	Condition 4 (Word baseline)	Condition 5 (Nonword baseline)	Target word
1	A1	B1	C1	D1	E1	T1
2	A2	B2	C2	D2	E2	T2
…	…	…	…	…	…	…
…	…	…	…	…	…	…
20	A20	B20	C20	D20	E20	T20
21	B1	A1	C1	D1	E1	G1
22	B2	A2	C2	D2	E2	G2
…	…	…	…	…	…	…
…	…	…	…	…	…	…
40	B20	A20	C20	D20	E20	G20

Stimulus in Each Block

Items	No. of items	Prime-target combination
Test items	12	word prime – word target
	8	nonword prime – word target
Filler items	12	word prime – nonword target
	8	nonword prime – nonword target

Appendix VI: Stimulus Allocation in Experiment 4 and Stimulus in Each Block

Stimulus Allocation in Experiment 4

Item no.	Condition 1 (Original word)	Condition 2 (Same-onset nonword)	Condition 3 (Same-rime nonword)	Condition 4 (Same-tone nonword)	Condition 5 (Word baseline)	Condition 6 (Nonword baseline)	Target word
1	A1	B1	C1	D1	E1	F1	T1
2	A2	B2	C2	D2	E2	F2	T2
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
40	A40	B40	C40	D40	E40	F40	T40

Stimulus in Each Block

Items	No. of items	Prime-target combination
Test items	13 or 14	word prime – word target
	26 or 27	nonword prime – word target
Filler items	14	word prime – nonword target
	26	nonword prime – nonword target

Appendix VII: Prediction of Lexical Activation by Four Models in Experiments 1 and 2

Activation of "bing1" predicted by the four models in each condition of Experiment 1

		Models			
Conditions	Input	COHORT I	COHORT II	TRACE	SHORTLIST
Condition 1 (Original word)	*bing1*	+	+	+	+
Condition 2 (Onset-altered word)	*sing1*	-	(+)	-	-
Condition 3 (Onset-altered nonword)	*kwing1*	-	(+)	+	-

Activation of "baau1" predicted by the four models in each condition of Experiment 2

		Models			
Conditions	Input	COHORT I	COHORT II	TRACE	SHORTLIST
Condition 1 (Original word)	*baau1*	+	+	+	+
Condition 2 (Rime-altered word)	*biu1*	-	-	-	-
Condition 3 (Rime-altered nonword)	*boe1*	-	-	+	-

Note:

All syllable markings are in accordance with *Yue yu pin yin zi biao* (The Linguistic Society of Hong Kong, 1997).